Remedial Investigation Work Plan

Tittabawassee River and Upper Saginaw River and Floodplain Soils
Midland, Michigan

Volume 1 of 2

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1. INTRODUCTION

This Remedial Investigation (RI) Work Plan (RIWP) has been prepared for the Study Area consisting of river channels and floodplains of the Tittabawassee River (TR) and Upper Saginaw River (USR), from the confluence of the Tittabawassee and Chippewa Rivers down to the 6th Street Turning Basin on the Upper Saginaw River. This RIWP has been prepared pursuant to Condition XI.B.5 of the 2003 Hazardous Waste Management Facility Operating License (License) issued by the State of Michigan Department of Environmental Quality (MDEQ) for The Dow Chemical Company (Dow) Midland Plant in Midland, Michigan (Midland Plant) (MDEQ, 2003b). This RIWP has been prepared to be generally consistent with the revised Scope of Work (SOW) for the Tittabawassee River and Floodplain Remedial Investigation developed and approved under the License (CH2M Hill, 2005d). This TR/USR RIWP has been prepared to meet the requirements of Michigan's Natural Resources and Environmental Protection Act (NREPA), 1994 PA 451 [Act 451], as amended, Parts 111 (Hazardous Waste Management) and 201 (Environmental Remediation), and Resource Conservation and Recovery Act (RCRA) regulations and standards of practice. It has also been prepared to be consistent with the Framework for an Agreement between the State of Michigan and The Dow Chemical Company (Framework), which was signed by Dow and MDEQ in January 2005. The Framework establishes the path forward for (1) initiating interim response activities (IRA) for the Study Area; (2) creating a defined process for addressing remaining concerns in the Study Area; and (3) providing a structure for Dow to resolve with finality potential claims arising from historical releases (Dow and MDEQ, 2005).

This RIWP describes work to be performed in offsite areas identified under Conditions XI.B.2 and XI.B.6 of the License, which require further corrective action in the Tittabawassee and Saginaw Rivers and floodplains. The Study Area begins at the confluence of the Tittabawassee and Chippewa Rivers upstream of the licensed study area boundary, which commences at the Midland Plant upstream boundary, and extends 22 miles to the confluence of the Tittabawassee and Shiawassee Rivers downstream of Greenpoint Island, and Dow has also agreed to include in this RIWP from this confluence point 6.5 miles downstream on the Saginaw River to the Sixth Street Turning Basin in the City of Saginaw. The inclusion of work on the Upper Saginaw is being done in advance of any regulatory obligations as set forth in the License to submit a scope of work for the Saginaw River by August 2007.

A map showing the location of the Study Area is provided on Figure 1-1.

The TR/USR Study Area activities will be coordinated with the <u>on-site</u> portions of the License, which require Dow to identify the potential for continuing sources and to perform an On-site Corrective Action and Monitoring Program. This will include coordination with work being done under License Conditions X.J., Facility Shallow Groundwater Monitoring Program; X.K., Ambient Air Monitoring; X.L., Soil Monitoring Programs; and XI.R. Source Control. Remedial investigations and corrective action activities for historical on-site or contiguous source areas are being conducted in parallel and in coordination with this RIWP pursuant to License Condition XI.C.1.

The Tittabawassee and Saginaw Rivers have been the focus of several investigations over the past several decades (see Section 2.2). These studies have primarily been directed towards gaining an understanding of flows and solids transport in the rivers and their floodplains over a range of flow conditions, and the distribution of contaminants in the river water, sediments, fish, and more recently floodplain soils.

In December 2005, a Tittabawassee River and Floodplain Remedial Investigation Work Plan (RIWP) (CH2M Hill, 2005d) was submitted to the Michigan Department of Environmental Quality (MDEQ) and United States Environmental Protection Agency (USEPA) to extend and complete these earlier studies. The December 2005 RIWP proposed a phased approach for site characterization using statistically based predictive models. On March 2, 2006 and April 13, 2006 MDEQ and USEPA issued Notice of Deficiency (NOD) comments on the December 2005 RIWP (MDEQ, 2006a; MDEQ, 2006b). In view of these NOD comments, MDEQ has requested, and The Dow Chemical Company (Dow) has agreed, to submit a new stand-alone RIWP by December 1, 2006. This document is intended to fulfill that commitment, and to comprehensively address the Tittabawassee River and Upper Saginaw River Study Area remedial investigation requirements identified in Dow's 2003 Hazardous Waste Management Facility Operating License.

In March 2006, Dow requested that Ann Arbor Technical Services, Inc. (ATS) review the December 2005 RIWP, existing data and historical information and prepare a geomorphological based Sampling and Analysis Plan (SAP) for the investigation of the Upper Tittabawassee River (UTR). The SAP prepared by ATS presented the *GeoMorph®* approach to address the investigation of contaminated sediments of the UTR and was submitted to MDEQ in partial response to the NOD comments on June 1, 2006, and was revised on June 30 and July 7, 2006. The UTR SAP describes the objectives and overall approach for geomorphic-based sediment and soil investigation in the upper 6 miles of the Tittabawassee below the confluence with the Chippewa River. On July 12, 2006, after a number of all day working sessions with Dow and its consultants, MDEQ approved the SAP as a pilot study for UTR Reaches A through O to demonstrate the usefulness of the *GeoMorph®* process. This approval was subject to limitations and exclusions outlined in their July 12, 2006 approval letter, which is included in Attachment L. When fully implemented, the UTR SAP will provide a geomorphology-based characterization of the UTR sufficiently comprehensive to evaluate risk management options (ATS, 2006b).

A number of the NOD comments issued by MDEQ and USEPA on March 2, 2006 and April 13, 2006 related to the proposed geospatial statistical model set forth in the December 2005 RIWP, the unbiased random sampling approach, the limited number of samples proposed, and the hypothesis that Constituents of Interest (COIs) were randomly distributed in portions of the Study Area. (MDEQ, 2006a; MDEQ, 2006b) In response, Dow has adopted a geomorphic based sampling approach to test the alternative hypothesis that COI distribution can be reasonably predicted by the fluvial geomorphological features of the river channel and floodplain, with a much greater sampling density and sample location approach to demonstrate the validity of the geomorphological approach. This approach was embodied in the UTR SAP conditionally approved by MDEQ and is the same approach being proposed in this RIWP for characterization of the distribution of COIs in the remainder of the Tittabawassee River below Midland and the upper 6.5 miles of the Saginaw River. The NOD comments relating to the Tittabawassee River site characterization have been addressed by the geomorphological approach employed in the conditionally approved UTR SAP and by the work proposed in this RIWP.

The TR/USR RIWP presented here includes, in summary form, new information that has become available through October 2006 from the *GeoMorph®* investigations conducted during the summer and fall of 2006 on the UTR. A complete report on the findings of the 2006 UTR *GeoMorph®* SAP work, will be reported in February 2007. This TR/USR RIWP also presents updated work plans for the Human Health Risk Assessment and the Ecological Risk Assessment along with work planned for 2007 and 2008. A final TR/USR Remedial Investigation Report will be submitted on December 31, 2008.

1.1 OBJECTIVES AND DELIVERABLES

This RIWP is intended to support and advance the overarching long term goal of Dow's corrective action program, which is to protect human health and the environment. Dow's approach to performing future corrective action builds on two fundamental aspects of the RCRA Corrective Action Program, developed by the U.S. Environmental Protection Agency (USEPA) and reflected in Michigan's Administrative Code as follows:

- An environmental risk management approach, intended to identify and confirm current and potential environmental risks and mitigate or manage those risks through remedy implementation.

- A results-based corrective action program, intended to achieve timely, efficient, and effective cleanup. USEPA describes results-based approaches as follows (USEPA, 2003):

  "Results-based approaches emphasize outcomes, or results, in cleaning up releases, and strive to tailor process requirements to the characteristics of the specific corrective action. Results-based approaches involve, where appropriate, setting goals, providing procedural flexibility in how goals are met, inviting innovative technical approaches, focusing data collections, and letting owner/operators undertake cleanup actions with reduced Agency oversight. Under such approaches, facilities are held fully accountable for the results they agree to achieve."

The principal objective of the work being proposed in this RIWP will be to develop information to support corrective action decision making. According to Michigan Administrative Code Rule 299.5528 (R 299.5528):

> *"The purpose of a remedial investigation is to assess site conditions in order to select an appropriate remedial action, if one is required, that adequately addresses those conditions."*

To accomplish this objective, this RIWP is designed to result in a Remedial Investigation report that will include the following deliverables by December 2008:

- A thorough identification of potential constituents of interest (PCOI) in the Study Area associated with Midland Plant operations.
- A characterization of the nature and extent of constituents of interest (COI) in the Study Area in the form of narrative, tabular and graphical presentations.
- A characterization of the fate and transport mechanisms that influence the distribution of COIs employing multiple lines of evidence, including geomorphological evaluations and numerical hydrodynamic modeling projections.
- An identification of probable exposure pathways, along with an estimate of risks to human health and the environment.
- Pilot studies of screened corrective action technologies in selected locations to assess field effectiveness in accomplishing the corrective action objectives and assess the environmental and ecological tradeoffs inherent in intrusive corrective actions.
- Information sufficient to support the preparation of subsequent feasibility studies, if needed, and any remedial action planning to meet remedial action objectives identified during the performance of the work outlined in this RIWP.

This RIWP addresses elements of R 299.5528(3) as appropriate and considers the results of previous investigations in the Study Area, and includes description of work underway or planned to provide multiple lines of evidence to support corrective action decision-making, as recommended in USEPA's 2005 Contaminated Sediment Remediation Guidance for Hazardous Waste Sites (USEPA, 2005), including:

- A detailed evaluation of Midland Plant manufacturing and waste management practice history;
- The PCOI/COI/TAL development process – reconciling The Dow Chemical Company manufacturing with environmental and physical chemical properties,
- Empirical measurements conducted on the geochemistry of affected soils,
- Measured flows, solids, contaminant fluxes in the rivers and floodplains under a range of flow conditions,
- Rates of solids deposition/erosion in the floodplain,
- Numerical hydrodynamic and particle transport modeling,
- A Screening Level Human Health Risk Assessment,
- A Human Health Risk Assessment,
- A Screening Level Ecological Risk Assessment,
- A Baseline Ecological Risk Assessment,
- Pilot studies to evaluate effectiveness and impacts of corrective action alternatives.

All of this work will be performed in concert with a Public Participation Program and according to the Schedules presented at the end of this RIWP.

The UTR SAP investigation work underway in 2006 is an important element in the multiple lines of evidence investigation approach outlined in this RIWP. The UTR SAP investigation is a geomorphic approach to investigating and evaluating the nature and extent of COI that may be present in sediments and soils along the UTR portion of the Study Area. These COI include chlorinated dioxins, chlorinated furans, and other chemicals described in detail in Section 5.1 of this RIWP. The *GeoMorph*® process being used in the UTR SAP is a comprehensive fate and transport methodology, combining fundamental information on COI environmental chemistry with fluvial processes and river geomorphology together with contaminant release history and anthropogenic influences along the river system. The objective of the *GeoMorph®* process is to provide a comprehensive characterization of in-channel and floodplain sediments and soils along the UTR. Deliverables will include:

- An assessment of the relevant physical and chemical properties of the COI and rationale used in their selection;
- Detailed topographic mapping of the project area with geomorphic features;
- Historical aerial photographic analysis for the relevant period;
- Detailed geomorphic feature mapping;
- An inventory of in-channel sediment characteristics, confirmatory sediment poling, and core sampling;
- Summary tables and concentration maps of the sediment and soil sampling information, with all locations described by reach and stationing coordinates;
- "Existing condition" surface-weighted average concentration (SWAC) maps using geomorphic polygons.

Once the *GeoMorph®* process has been demonstrated on a pilot basis in the UTR and approved by the MDEQ, the process will be extended to the Middle and Lower Reaches of the Tittabawassee River and to the Upper Saginaw River, with a goal of having all Remedial Investigations for this Study Area completed by the end of 2008.

1.2 REPORT ORGANIZATION

This RIWP is divided into two Volumes, each of which includes the following primary elements:

Volume 1

RIWP Overview and Background; Current Conditions; History; PCOI Selection; Conceptual Site Model; *GeoMorph*® Investigation Approach; Pilot Corrective Actions Studies; Public Participation Programs; and Schedules

- An overview of the project background and a brief description of the literature review that was undertaken to identify and document existing sources of data and analysis on the Study Area.

- A detailed summary of current conditions within the Study Area updated to include the preliminary findings of the *GeoMorph®* Sampling and Analysis work conducted on the Upper Tittabawassee River during the summer and fall of 2006.

- A detailed history of plant operations and waste management practices, including a Timeline showing chemicals produced, waste management practices, and the advent of environmental statutes and regulations.

- A detailed evaluation of constituents of interest (COI) based on the Midland Plant production history, including a description of the decision making process used to arrive at the Target Analyte Lists to be used in defining the nature and extent of contamination in the rivers and their floodplains.

- An updated Conceptual Site Model (CSM) integrating existing information on physical conditions, the nature and extent of hazardous substance releases and impacted media, environmental fate and transport, land development, and potential human and ecological receptors.

- A description of the geomorphic approach to the planned remedial investigation activities needed to complete the definition of the nature and extent of contamination within the Study Area, along with the approach to assessing the fate and transport of contamination presently deposited in the natural levees along the river systems and the planned statistical approaches to evaluating the data.

- A description of corrective action alternatives and pilot studies currently under consideration for both low flow and high flow conditions**.**

- An updated Public Participation Program.

- A planned schedule of activities for completing the Remedial Investigations on the Tittabawassee and Upper Saginaw Rivers by the end of 2008**.**

Volume 2

Screening and Baseline Ecological Risk Assessments; Human Heath Risk Assessment

- The first step in the (ERA) process is a Screening Level Ecological Risk Assessment (SLERA), or Tier I ERA, in which the objective is to identify and document conditions that do *not* warrant further evaluation in a more refined Baseline Ecological Risk Assessment (BERA). The goal is to eliminate insignificant hazards while identifying contaminants whose concentrations are sufficiently great as to potentially pose risks to ecological receptors.

- The BERA work plan is designed to provide a survey of species-specific dietary exposure concentrations and tissue residue concentrations in wildlife that are potentially exposed to PCDFs and TCDFs in the Tittabawassee and Saginaw Rivers and floodplain soils. The BERA is designed to satisfy the requirements of Operating License Condition X1.B.v.3 to conduct an ecological risk assessment (ERA) as a part of the Remedial Investigation (RI) process.

- The purpose of the HHRA in Volume 2 is to assess potential human health risks from historic releases from the Midland Plant. As a part of this work, the HHRA will finalize the chemicals of potential concern, identify receptor populations along with the relevant complete exposure pathways, set the algorithms used to quantify exposure and the input variables needed, and to derive in collaborations with MDEQ, needed toxicity criteria, and define models to be used.

2. BACKGROUND

This section provides an overview of the project study area, a brief description of the literature review and previous investigations to identify and document existing sources of data and analysis on the RI Study Area, and a summary of previous corrective actions undertaken in the Study Area. An overview of the Study Area is shown in Figure 1-1.

2.1 PROJECT AREA OVERVIEW

2.1.1 Tittabawassee River

The Tittabawassee River is a tributary to the Saginaw River, draining 2,600 square miles of land in the Saginaw River Watershed. The Tittabawassee River, along with the Shiawassee, Flint, and Cass Rivers, comprise approximately 84 percent of the total Saginaw River drainage area (MDNR, 1988). The Tittabawassee has the largest drainage area covering 39 percent of the total area draining to the Saginaw River.

There are a number of dams on the upstream portion of the Tittabawassee River. The dams are located at Secord, Smallwood, Edenville, Sanford, and Midland (Dow). The dams upstream of Midland were constructed in 1925 to generate hydroelectric power and provide limited storage and flood control during storm events for the Cities of Midland and Saginaw. In addition, a Beaverton hydroelectric dam was installed further upstream in 1918. The current operation of the hydroelectric station at Sanford results in water releases from Sanford Dam during peak electricity usage periods to provide peaking power to Consumer's Energy. Sanford Lake has limited flood storage capacity due to a narrow range of permitted lake levels. Below the Dow Dam, the river is free flowing to the confluence with the Shiawassee and Saginaw Rivers.

The Tittabawassee River is the receiving water for various industrial and municipal wastewater discharges. Some discharge directly into the river, and some discharge into the major tributaries of the Tittabawassee River: the Salt, Tobacco, and Chippewa Rivers. Past industrial inputs include wastes from chemical, plastics, can manufacturing, and photographic industries (Rossman, et al., 1983). A significant smaller tributary is Lingle Drain, located at the south end of the Midland Plant, which has been a receiving stream for both municipal and industrial discharges over time.

2.1.2 Upper Saginaw River

The Saginaw River is located within the Saginaw Bay and River watershed and drains 6,300 square miles of land. It is formed by the confluence of the Tittabawassee River and the Shiawassee River just south of Saginaw, Michigan. The river itself is relatively short, with only 22.3 miles of length. Most of the Saginaw River flow originates in its major tributaries with 39 percent of flow contributed by the Tittabawassee River, 11 percent of flow contributed by the Shiawassee River, 20 percent of flow contributed by the Flint River, 14 percent of flow contributed by the Cass River and 16 percent of flow contributed by other sources. Most of the rivers in the watershed, including the Cass and Flint Rivers, indirectly discharge into the Saginaw River. The Flint River discharges into the Shiawassee River approximately six miles upstream of the confluence of the Tittabawassee and Shiawassee Rivers. The Cass River also discharges into the Shiawassee River, approximately five miles downstream of the Flint River and about one mile upstream of the Tittabawassee/Shiawassee/Saginaw confluence.

The Saginaw River flows through Saginaw, Michigan and from there to Bay City, where the river discharges into Saginaw Bay (Figure 1-1). Saginaw Bay water surface elevations and seiche effects (oscillations in water surface elevations caused by meteorological events) can affect Saginaw River water levels and flow rates for its entire length. The lower tributaries of the Saginaw River and the confluence area upstream of the Saginaw River can also be affected by varying Saginaw Bay water levels.

Like the Tittabawassee River, the Saginaw River is a receiving water from various industrial and municipal wastewater discharges. Some discharge directly into the river, and some discharge into the major tributaries of the Saginaw River. Municipal dischargers include the cities of Saginaw, MI and Bay City, MI. Past industrial inputs include wastes from chemical, plastics, can manufacturing, and photographic industries. (Rossman, 1983). This RIWP focuses on the Saginaw River from the confluence of the Tittabawassee River and Shiawassee Rivers north and east to the Sixth Street Turning Basin in Saginaw (Figure 1-1).

2.2 DOCUMENT REVIEW AND PREVIOUS INVESTIGATIONS

ATS has performed a limited review and re-analysis of the available environmental data/information on the Upper Tittabawassee River. Several environmental data collection studies have been conducted in the Tittabawassee River area since 1970. A number of investigations have also been conducted on the Saginaw River and its tributaries to establish an overview of the nature and extent of COI in contaminated sediments. The authors of these studies include Dow, Dow consultants, MDEQ, the U. S. Army Corps of Engineers (USACE), USEPA, United States Geologic Survey (USGS), and others.

The following is a list of the previous investigation documents that were reviewed in the development of this RIWP:

- Public Sector Consultants, Inc., 2000, *Measures of Success: Addressing Environmental Impairments in the Saginaw River and Saginaw Bay.* (PSC, 2000)
- Public Sector Consultants, Inc., 2002*, Targeting Environmental Restoration in the Saginaw River/Bay Area of Concern: Update of 2001 Remedial Action Plan* (PSC, 2000)
- MDEQ 2002, *Baseline Chemical Characterization of Saginaw Bay Watershed Sediments*. (MDEQ, 2002a)
- MDEQ 2003, *Final Report Phase II Tittabawassee/ Saginaw Rivers Dioxin Flood Plain Sampling Study*, June. (MDEQ, 2003a)
- Galbraith, 2003, *Tittabawassee River Aquatic Ecological Risk Assessment*. August. (Galbraith, 2003)
- Galbraith, 2004, *Tittabawassee River Floodplain Screening-Level Ecological Risk Assessment*. (Galbraith, 2004)
- USACE, 2004, *Upper Saginaw River Phase II Report Dredged Material Management Plan Study.* (USACE, 2004)
- CH2M Hill, 2004, *Saginaw River Watershed Scoping Investigation Sampling and Analysis Plan.* (CH2M Hill, 2004)
- CH2M Hill, 2005, *Saginaw River Baseline Report*. (CH2M Hill, 2005a)
- CH2M Hill, 2005, *Sediment Evaluation Report, Upper Saginaw River.* (CH2M Hill, 2005b)
- CH2M Hill, 2005 Tittabawassee River Floodplain Scoping Study Work Plan-Revised July 2005. (CH2M Hill, 2005c)
- CH2M Hill, 2005, Tittabawassee River and Floodplain Remedial Investigation Work Plan, December 2005 (CH2M Hill, 2005d)
- ATS, 2006, Conceptual *GeoMorph®* Scoping Study for the Upper Saginaw River (ATS, 2006a)

The relevant and suitable data from previous investigations are summarized in Sections 2.2.1 and 2.2.2, Data/Information Review and Suitability Analysis. The objectives of these studies varied, ranging from general contaminant, sediment and flow characterization to preliminary human health and ecological risk assessments. With such varied study objectives, a careful screening of the historical information and data has been performed to assess suitability for use in the current and proposed site characterization work.

2.2.1 Data/Information Quality And Suitability Categories

The purpose of the background data review conducted in 2006 was to evaluate the suitability of this information to the *GeoMorph®* process. The means, methods, and procedures used to collect historical data were examined as part of the data re-analysis. Data suitability was determined by reviewing procedures used to select sampling locations, sampling intervals, sediment description process, sample analysis process, analytical parameter selection, and sediment poling techniques. Additional information reviewed included available aerial photography, mapping, furan and dioxin chemistry data, other chemistry data, and river elevation/flow data. For this RIWP a consistent process and uniform standards were used to assess the overall data quality, based on requirements specific in the project Quality Assurance Project Plan (QAPP) (ATS, 2006). The objective of the suitability analysis was to determine which information/data met data quality objectives of the QAPP, were consistent with applicable USEPA guidance, and therefore were valid for the intended purpose. To the extent possible, all such information/data have been incorporated into the *GeoMorph®* site characterization and this RIWP.

As a general reference, a primary source of information for Sections 2 through 5 of this RIWP was the December 2005, Tittabawassee River and Floodplain Remedial Investigation Work Plan (CH2M Hill, 2005d). Data and other technical information from that document have been assessed for suitability, and incorporated into this RIWP as useful and appropriate.

2.2.2 Summary Of Data/Information Suitability

Soil and Sediment Sampling Intervals: Previous investigations have used classic fixed interval sampling for soils and sediments. Fixed interval sampling is generally not suitable for classification of geomorphic units because it tends to obscure the interrelationship of stratigraphic units. Therefore, most previous soil sampling results are confounded by this factor and must be carefully interpreted in light of that.

Soil Classification and Stratigraphy: The *GeoMorph®* site characterization process utilizes soil science classifications of sediment and soil stratigraphic layers, rather than more typical geologic science classifications. For that reason, the logs generated by the two different classification systems are not directly comparable, and require some degree of translation to be used interchangeably.

Aerial Photography and Mapping: LiDAR topographic mapping used as the basis for work in the 2005 RIWP was found to be acceptable for low resolution geomorphic mapping and therefore was used to generate preliminary graphics depicting geomorphic surfaces in the UTR. However, LiDAR is not suitable for high resolution mapping and consequently ATS commissioned a complete high resolution aerial photographic survey of entire Tittabawassee River (22 miles) and Upper Saginaw River (upper 6.5 miles) in April 2006. Detailed mapping to 1 foot contours has been projected for the UTR from this set of aerial photographs, and this mapping will be used to revise the preliminary geomorphic surfaces for the UTR SAP report due February 1, 2007. High resolution mapping will be projected for the remainder of the TR and the USR by March 31, 2007.

Chemistry Data: Most chemistry data for chlorinated furans and dioxins were found to be suitable based upon the analytical methods used, the NELAC "level IV" post-acquisition data validation process used, and the data quality requirements of the UTR QAPP. Therefore, these data points have been brought forward into the current site conditions analysis. This includes all furan and dioxin data generated in 2005. Other chemistry data have also been, or will be, incorporated into this analysis so long as the data quality objectives in the QAPP have been met, and the data are useful and appropriate for the purpose intended.

2.3 PREVIOUS CORRECTIVE ACTIONS

The following section summarizes previous Interim Response Activities (IRA) conducted within the Study Area in accordance with the Framework Agreement (Dow and MDEQ, 2005) and the Scope of Work prepared pursuant to Dow's Hazardous Waste Site Operating License Condition XI.B.2. (MDEQ, 2003b) IRAs are short-term corrective actions taken to control ongoing risks while site characterization is underway and before a final remedy is implemented.

Three sets of IRAs are discussed below. The first set addresses potential direct contact exposure routes on public recreation sites lying within the Tittabawassee River floodplain. The second set of IRAs addresses corrective actions taken on Dow Chemical property. The third set addresses Priority I and II activities (as defined in the Framework Agreement) that mitigate potential human exposure to furans and dioxins within residential homes and properties impacted by periodic flooding of the Tittabawassee River.

2.3.1 Floodplain Recreation Areas Interim Response Actions

2.3.1.1 Center Road Boat Launch Interim Response Actions

Interim remedial activities have been conducted at Center Road Boat Launch located in Saginaw County on Center Road south of Michigan Road. The Center Road Boat Launch is approximately 5 acres and consists of a boat launch, observation deck and gravel parking lot. The purpose of the activities was to address potential direct contact exposure routes from surface soils within the floodplain of the Tittabawassee River and potential track out issues within the gravel parking areas of the boat launch. Site activities were conducted in June 2006. The project was completed by Saginaw Township with oversight by URS and funding by Dow.

After heavy rainfall events or flooding, potential track out material was observed within the lower areas of two approximately ¼ acre areas on the east and west portion of the parking lot adjacent to the surface water drainage culverts. To deter driving within the lower areas of the parking lot and to address potential track out, the ¼ acre areas adjacent to the drainage culverts were closed to the general parking areas by driving guide rail posts. New topsoil was placed within the areas to promote vegetative growth in the addressed areas and then seeded. In addition, during 2004 selected trees were removed along the river bank, leaving root masses intact to minimize potential for erosion, and gravel was placed along the boat ramp to minimize the potential direct soil contact exposure.

Supplemental activities have included frequent inspection of the boat launch area to observe potential track out conditions. If minor sediment or silt was observed, the material was removed and transported and disposed of at the Waste Management – Peoples Landfill in Birch Run, Michigan. The activities have also included power washing of the area asphalt roads. The projects were completed by Saginaw Township and oversight was provided URS and funded by The Dow Chemical Company.

2.3.1.2 Freeland Festival Park Interim Response Actions

Interim remedial activities were conducted at Freeland Festival Park located in Tittabawassee Township, Freeland, Michigan from June 2005 to October 2005. The purpose was to address potential direct contact exposure routes from surface soils within the floodplain of the Tittabawassee River. The project was divided into eight phases that included clearing and grubbing, decking foundation, deck system, earthworks and riverbank stabilization, riverbank wall construction, electrical, asphalt paving and landscaping. The activities were completed by Tittabawassee Township with engineering support by Wilcox and Associates, and funded by The Dow Chemical Company.

The park was shut down between June 2005 and September 2005. Public access was restricted during construction by barriers and tape. Clearing and grubbing was completed in June 2005. Heavy vegetative growth was removed from the area where the decking system was to be installed and along the riverbank. To contain silt movement during construction, a floating silt boom (approximately 500 feet) was installed in the river along the working area of the deck construction. In addition, silt fencing was installed along the top of slope along the river bank and drainage areas within the western and southern portions of the park to control soil runoff during storm events. Placement of the decking foundation was also started in June 2005. Helical piers were installed along the river bank using directional drilling methods to provide primary decking support. The piers were installed along the riverbank for the decking platform. In June 2005, the riverbank was graded within the decking area to the design elevation, geotextile was placed, and heavy rip rap was installed as slope protection within and around the decking system. Overburden soils (cut soils) were temporarily stockpiled on-site and subsequently transported and disposed of at the Waste Management – Peoples Landfill in Birch Run, Michigan.

After the heavy rip rap placement and the decking foundation was completed, the decking system was installed. Dolphin piers were placed to protect the deck system from river debris. The primary support structure was placed across the drilled pier system and then finished with HDPE composite lumber.

Construction of the riverbank wall was also started in late June, beginning with soil excavation of the riverbank wall foundation. The soil was stockpiled with other material destined for disposal at Waste Management - Peoples Landfill. The wall started near the western limit of the park and followed the top of riverbank slope to the eastern limit of the park. The wall was tied into the constructed decking system and park observation platform. The formed concrete wall extended approximately 3.5 feet above ground surface and was completed with a stone finish. Wall and park lighting were completed, including lighting of the park pavilions.

Following completion of the wall and decking construction, surface restoration of the park areas was completed. A new asphalt path accessing pavilions and the observation deck was installed. A layered stone and compacted sand sub-base were installed in September 2005, and then finished with structural asphalt surface and a new asphalt wearing course. The open vegetated areas of the park were cleared and then graded to provide positive control of surface drainage. A subsurface drainage system consisting of piping and catch basins to manage storm water from the parking lot and the open areas of the park was installed, with outlet drainage to the western portion of the park. Six to eight inches of clean topsoil was then spread across remaining disturbed areas of the park. Topsoil came from an off site borrow location. The topsoil was spread, final graded and then seeded. Landscaping of the park entrance and area adjacent to the decking entrance were also completed in September 2005.

Supplemental projects have been completed on an as needed basis since April of 2004. A hand wash station is mobilized to the park in late March or early April and maintained until November. The station is serviced on an as needed basis. Supplemental projects have also included fertilizing vegetative areas of the park, and maintenance of the decking system. To maintain good vegetative growth across high utilization areas of the site, the vegetation is inspected and fertilized in the spring and fall of the year. Bare spots or weak vegetative growth is over-seeded to facilitate vegetative re-growth.

2.3.1.3 Imerman Park Interim Response Activities

Interim response activities were conducted at Imerman Park, located at 3495 Midland Road in Saginaw, Michigan, between November 2004 and April 2006. The park is approximately 96 acres in size and is operated by Saginaw County Parks and Recreation. The objectives of the interim response activities at Imerman Park were to mitigate the potential for direct contact exposure to surface soils within the floodplain and to address erosion along the Tittabawassee River. The activities were selected to primarily address high use areas of the park. The projects have been completed by Saginaw Parks and Recreation with engineering support from Spicer's Engineering, with oversight by URS, and funding by The Dow Chemical Company.

The interim response activities were conducted in two principal phases. Phase I was completed from November 2004 to May 2005 and primarily focused on the area near the park's main pavilion. Phase I activities included placement of heavy rip rap, fencing to restrict access to the riverbank slope, concrete and asphalt pathways, new fishing and observation platforms, new topsoil and establishment of vegetation. Phase II was completed from September 2005 to April 2006 and included relocation of the Dog Park, replacement of gravel pathways with concrete pathways, paving of the overflow parking lot and construction of a cross country lay down area.

Supplemental project have been completed on an as needed basis since April of 2004, including maintaining hand wash stations, maintaining approximately 5,000 lineal feet of wood chipped trails, fertilizing high use vegetative areas of the park, and maintenance of the boat launch area.

The initial Phase I construction work began in November 2004 with work at the main park pavilion, pavilion parking area, and the gravel overflow parking lot. These areas were restricted to the public during construction by barriers and tape. A floating silt boom was installed within the river along the working area to control silt transport in the river during construction activities (from approximately 500 feet upstream to 1000 feet down stream of the pavilion). The eroded riverbank in this area was uniformly re-graded to reduce the slope along the river, resulting in significant soil removal. The removed soil was temporarily stockpiled and subsequently disposed at the Waste Management – Peoples Landfill in Birch Run, Michigan. After regrading, geotextile was extended from top of slope to toe of slope at the river. Heavy rip rap was then placed by an excavator on the graded slope area along the river.

The foot traffic use area around the main pavilion was also upgraded. Silt fencing was installed along the top of slope, and a concrete pathway was placed leading from the pavilion to the east (upstream). Prior to the placement of concrete, a stone aggregate base was placed to provide a stable surface. The concrete pathway was placed to connect the main pavilion to a new river observation deck located approximately 250 feet east of the main pavilion. The observation deck construction included the installation of wood piles, a steel support structure, a concrete foundation and wooden decking. Decorative iron fencing was then placed adjacent to the top of slope and was terminated at the observation decking to restrict access to the river bank. Split rail fencing was also placed to restrict access to areas that were disturbed east of the observation decking.

A new fishing platform was constructed downstream of the main pavilion. The platform included a concrete foundation on the shoreline to stabilize the structure, tie down piles, and a prefabricated wood floating platform. New asphalt paths were constructed around the main pavilion and tied into the concrete walkway, fishing platform, and main pavilion parking area. Prior to placement of the asphalt, a stone base was placed to provide a stable sub-grade. After completion of the asphalt trails and the fishing platform, six inches of topsoil was placed in disturbed areas and seeded to establish vegetation.

In September 2005, Phase II interim response activities began with the removal of the old Dog Park, construction of a cross country lay down area, construction of a asphalt overflow parking lot, replacement of gravel paths with concrete walkways, grading of surface water drainage pathways, construction and topsoil placement within the new Dog Park, and construction of an auxiliary parking lot and a new gate house.

The footprint of the old Dog Park, formerly located in the back of the park adjacent to the boat launch area, was used as the limits of the new cross country lay down area. The sub-grade of the cross country lay down area was prepared by replacement of existing topsoil with a compacted sand and stone aggregate base. After the base was compacted and graded, an asphalt wearing surface was placed, and a curbing structure and roller blade surface were placed as a final surface so the area could alternatively be used as a roller blade hockey area. Removed soil was transported and disposed of at the Waste Management – Peoples Landfill. Subsurface drain piping and storm water grates were placed around the area to manage surface and subsurface drainage. The drainage was directed to an existing channel that borders the park to the south approximately 1,800 feet from the constructed cross country lay down area.

The overflow parking area is a gravel parking area in the central portion of the park adjacent to the main pavilion area. The existing stone sub-base was graded and supplemented with an additional thickness of stone aggregate. The area was then surfaced with asphalt and a surface drain was placed along the southern boundary of the parking lot to manage surface water drainage. The collected storm water flows east to an existing drainage channel east of the main pavilion parking area. Culverts were installed beneath the entrances of the overflow parking lot and main pavilion parking areas.

An existing gravel path leading from the front main parking area to the restroom was compacted and overlain with concrete. The path was graded to match existing grades and topsoil was placed and seeded to complete final grading of areas adjacent to the new path.

A new Dog Park, parking area and gate house were constructed near the front of the park at the same time the old Dog Park was being removed. New chain link fencing was installed in the large open space north of the park entrance to serve as the new Dog Park. This area was selected because it was at or above the FEMA estimated 100 year floodplain. New topsoil was installed within the fenced area to facilitate drainage.

The former gate house was demolished and replaced with a new gate house in the same general area. A new parking lot was constructed adjacent to the gate house to serve as parking for the new Dog Park. The compacted sand and aggregate sub-grade was placed to support the gate house and new parking lot. The gate house was then constructed as a single story building on a concrete slab foundation. The adjacent parking lot was surfaced with asphalt. Most of this work was completed prior to December 2005. Overburden soils within these flood plain construction areas were excavated and disposed of at the Waste Management – Peoples Landfill.

During the winter and early spring of 2006, a drainage issue was identified that included ponding and sheet flow across the gate house slab. A subsurface drain and storm water grating system was installed within the new Dog Park and around the gate house. After the subsurface drainage was installed, new topsoil was placed, graded and seeded. In addition, new trees were planted for landscaping and aesthetic appeal.

Supplemental activities have been completed on an as needed basis since April of 2004 and have included maintaining hand wash stations, maintaining approximately 5,000 feet of wood chipped trails, fertilizing high use vegetative areas of the park, and maintenance of the boat launch area. Three hand wash stations are mobilized annually to the park in late March or early April and then maintained until November. The stations are serviced on an as needed basis. The wood chipped trails across Imerman Park are monitored for bare spots or damage after each flood event. The trails are maintained by placement of 2-3 inches of new wood chips as needed. To maintain good vegetative growth in high use areas, existing vegetation is inspected and fertilized in the spring and fall of each year. Bare spots or weak vegetative growth is over-seeded to facilitate a thick vegetative growth. The boat launch area is inspected periodically and maintained as needed. If sediment build-up or track out material is observed on the concrete boat ramps, the boat ramp area is scraped and sediments are removed. The removed material is transported and disposed of at the Waste Management – Peoples Landfill.

2.3.1.4 West Michigan Park Interim Response Activities

Interim response activities were conducted at West Michigan Park located in Saginaw Township on West Michigan Road in Saginaw County during October 2005. West Michigan Park is approximately 18 acres in size and consists of a parking area, playground equipment and large open grass spaces used for soccer or other recreation. The park is entirely within the floodplain of the Tittabawassee River. The interim response activities were intended to mitigate potential direct contact exposure from the sand around the playground equipment. The project included removal of the top six inches of the existing sand around the playground equipment and replacement with rubber mulch chips to enhance fall protection. Stone was placed on the canoe launch area to minimize direct contact exposure and trees leaning over the river were cut, leaving root masses intact, to minimize the potential for erosion. The projects were completed by Saginaw Township, with oversight by URS and funding by The Dow Chemical Company.

Four to six inches of the existing sand surrounding playground equipment was removed and stockpiled over an area of approximately 1,500 square feet. After removing the upper layer of sand, 20 tons of rubber mulch was hand placed around the playground equipment. Prior to placement of the mulch, a geotextile layer was placed on top of the underlying sand cushion layer to assist in containing the rubber mulch. The disturbed existing grassy areas adjacent to the playground equipment were dressed with additional topsoil and reseeded to promote vegetative growth. Sand removed from the area was disposed of at the Waste Management - Peoples Landfill in Birch Run, Michigan. Supplemental activities have been completed on an as needed basis since April of 2004 and have included maintaining the hand wash station and fertilizing and over-seeding high use areas of the park. A hand wash station is mobilized to the park each year in late March or early April, and maintained until November. The station is serviced on an as needed basis.

2.3.2 On-Site Corrective Actions

Ongoing on-site corrective actions have been performed in accordance with the License and periodic reports are provided to MDEQ in accordance with the License Conditions.

2.3.3 Interim Response Activities on Priority I and II Properties

Existing data indicates that properties that flood frequently or were flooded during the March 2004 high water event may be contaminated. A number of these properties are actively used for residential, agricultural, and recreational purposes. The primary objectives of the Priority I and Priority II IRAs were to identify and mitigate potential human exposure to furans and dioxins that have been, or may be found in soils prior to implementation of final response activities. Priority for interim, short-term activities will be given to properties with residential use and soil concentrations that are known or presumed to exceed the Agency for Toxic Substances and Disease Registry (ATSDR) action level of 1,000 parts per trillion toxic equivalent (ppt TEQ). Initially, this will be determined by identifying those properties that flooded in March of 2004. Residential use includes properties with exposure potential that is similar to residential (e.g., schools, child care facilities, nursing homes, adult day care facilities).

The implementation of the Priority I and II Interim Response Activities followed the sequence listed below:

- Properties that were subject to flooding by the Tittabawassee River and are, therefore, likely to have elevated concentrations of chemicals of concern were identified.
- The priority for mitigating exposure to potentially elevated concentrations of dioxins and furans was established.
- A range of interim response activities were identified and implemented for specific land uses that were acceptable to the property owner given property-specific conditions, or presumptively. Priority has been given to identification of properties with residential use that exceed or are presumed to exceed the ATSDR action level of 1,000 ppt TEQ.
- Implementation of the mitigation option(s) agreed to by the property owner/occupant to limit or prevent exposure to contaminants prior to the implementation of the final remedy.
- Implementation of exposure mitigation measures in response to flood events.

Properties assessed for potential IRAs were limited to those properties located along the Tittabawassee River from the upstream boundary of the Dow Midland Facility to the confluence with the Shiawassee River in Saginaw County.

2.3.3.1 Priority I

Mitigation measures offered to the property owner(s) included:

- Education and outreach, offered to all.
- Provide temporary exposure barriers for exposed or poorly covered areas used by the owner: Cover (e.g., sod, soil, raised garden bed, raised area, paving, mulch.)
- Augment existing cover.

- Provide paving or cover at entryways to minimize track-in of contaminated soils.
- House cleaning, including cleaning of carpeting, interior ductwork, and other surfaces where contaminants may potentially exist.
- Identification of affected areas (known through sampling and or identification of flooding impacts) by means agreeable to resident (e.g., flagging, marked aerial photographs).
- Monitoring, maintenance, and restoration of mitigation measures as necessary.
- Removal of water and deposited sediment and soil after flooding events.
- Other reasonable mitigation measures identified and agreed to by property owner(s) based on their uses of the property.

2.3.3.2 Priority II

Mitigation measures to be offered to the property owner(s):

- Education and outreach, offered to all.

Additional mitigation options that may be considered:

- Identify affected areas (through sampling and demarcation [e.g., flagging]).
- Provide temporary exposure barriers as described for Priority I.
- House cleaning as described for Priority I.
- Other reasonable mitigation measures identified and agreed to by property owner(s) based on their uses of the property.
- Monitoring, maintenance and restoration of mitigation measures as necessary.

Table 2-1 shows which mitigation measures were accepted by the various owners/occupants of the Priority I and II parcels.

Table 2-1 Accepted Priority I and II Interim Response Activities

	Carpet Cleaning	Hard Floor Cleaning	Horizontal Hard Surface	Cleaning of Heating System	Replacement of Furnace Filter	Landscaping	Doormat	Refused Services	Total Parcels Eligible for Mitigation Options
Priority I Parcels	78	65	63	79	73	86	19	16	141
Priority II Parcels	101	95	95	102	102	38	62	133	532

3. CURRENT CONDITIONS

This section presents a description of current conditions on the Tittabawassee and Upper Saginaw Rivers and floodplains within the Study Area. It summarizes environmental information relevant to establishing the scope for the future characterization, including a description of the physical characteristics of the Study Area, a summary of the potential historical sources of hazardous substances, and a preliminary assessment of media in the Study Area that may have been impacted by releases of hazardous substances based on available data.

This section incorporates information from a variety of previous investigations. Principal sources of the information presented in this RIWP were the 2005 Tittabawassee River Floodplain Scoping Study (Scoping Study) (CH2M Hill, 2005c); the December 2005 Tittabawassee River and Floodplain Remedial Investigation Work Plan (CH2M Hill, 2005d); and the USR Scoping Study initially submitted to MDEQ as a Conceptual SAP on March 1, 2006 and later resubmitted on March 24, 2006 as a Conceptual *GeoMorph®* Scoping Study for the Upper Saginaw River (ATS, 2006a).

3.1 PHYSICAL SETTING

The characteristics of the Tittabawassee and Saginaw River valleys influence the distribution of constituents released from the Midland Plant, potential exposure to those constituents, and the development and evaluation of potential remedial alternatives. An overview of the physical setting of the Study Area is presented below.

3.1.1 Geology and Hydrogeology

The following sections briefly describe the geology and hydrogeology of the Tittabawassee and Saginaw River valleys.

3.1.1.1 Geology

Glacial deposits are present at the ground surface in the region of the Tittabawassee and Saginaw River channels and floodplains. South of Midland, Pennsylvanian-age sedimentary bedrock is overlain by 150 to 400 feet of unconsolidated glacial deposits. The glacial sediments were deposited during the Pleistocene Epoch as glaciers advanced and retreated across the Midland area (Dow, 2002). The glaciers deposited glacial till composed of ground rock onto the landscape, with silt, sand and gravel deposited in melt water channels. Subsequent glacial advances compressed the till with continental ice sheets up to one mile thick, and additional layers of glacial sediment were deposited during subsequent retreats. After the final glacial advance came to a close, melt water ponded at the edge of the retreating ice, forming ice marginal lakes. Large lakes formed in areas where the land was depressed from the weight of the glacier or where the glaciers blocked natural drainage patterns. Nearshore sand layers and small dunes were deposited on top of the lacustrine (lake) bottom clay-rich sediments as the shorelines retreated (Dow, 2002). These lakebed clay and sand layers form the primary surficial deposits in the Tittabawassee and Saginaw Rivers and floodplain Study Area.

The Tittabawassee and Saginaw Rivers have eroded through the surficial sand deposits and much of the lakebed clay units to form the floodway. In places the rivers have eroded down to the glacial till deposits. The lakebed clay and the glacial till deposits represent materials deposited before any modern human activity in the area. Within the floodway, fluvial sand, silts, and clays have been deposited by floodwaters since the retreat of the glaciers from the area several thousand years ago. A small fraction of these fluvial deposits have been deposited during the last hundred years.

3.1.1.2 Hydrogeology

The Midland Plant is at the northwestern end of the Tittabawassee River and floodplain portion of Study Area. Although limited deep soil boring information is available for the floodplain between Midland and the confluence of the Tittabawassee and Shiawassee Rivers, drillers' logs filed with the State for the installation of domestic water wells indicate that hydrogeologic conditions in the floodplain are similar to those in Midland as described below. Additionally, limited drilling and soil sampling were conducted in several areas along the Tittabawassee and Saginaw River floodplains during several recent field events (CH2M Hill, 2005c; LTI, 2005a).

Descriptions of the hydrogeologic units below are based on information provided in Dow's 2002 License reapplication (Dow, 2002). Hydrogeologic units, from deepest to shallowest, are as follows: bedrock, the Regional Aquifer, glacial till, lakebed clay, and surface sands. Groundwater contained in bedrock occurs primarily in sandstone layers. The potentiometric head in the bedrock aquifer is higher than the head in the Regional Aquifer, resulting in an upward hydraulic gradient. The Regional Aquifer overlies bedrock in some areas and consists of well-sorted sands and gravels inter-layered with silt and clay seams. The low permeability of the overlying glacial till causes the Regional Aquifer to behave as a confined aquifer with an artesian head. Artesian conditions are common to the southwest of the Study Area because of the generally lower ground elevation.

Groundwater is present throughout the glacial till at saturation, although the extreme compaction of this unit has reduced effective porosity and permeability. Sand bodies of significant size, generally referred to as glacial till sands, occur in the glacial till. Glacial till sands are highly variable in length, thickness, and vertical location within the glacial till, and are relatively more permeable than the till.

The lakebed clay is generally considered an aquitard, although some water is contained in thin, discontinuous silt layers interbedded with the lakebed clay. The lakebed clay acts as a barrier to downward movement of groundwater.

Where the surface sands overlie the lakebed clay, the sands form an unconfined aquifer. Where present, the groundwater in the surface sands varies in both quantity and quality.

The majority of households and commercial establishments located on or adjacent to the Tittabawassee and Saginaw River floodplains obtain their water from municipal systems (MDEQ, 2003a). However, some residences south and east of Midland along the Tittabawassee River continue to acquire potable water from groundwater (MDEQ, 2003a).

3.1.2 Climate and Meteorology

The Midland area is characterized by a continental climate regime, with winter temperatures cold enough to sustain stable snow cover and relatively warm summer temperatures. The mean temperature for the area is 48 degrees Fahrenheit (°F). The minimum average temperature is 22°F (January), and the maximum average temperature is 72°F (July). Between 1896 and 2002, the Midland area's average monthly precipitation ranged between 1.4 inches (February) and 3.1 inches (September), with a monthly average of 2.3 inches and an annual average of 27 inches. Wind direction is typically to the east-northeast, regardless of season.

According to annual measurements recorded in Midland from 1950-1951 through 1979-1980, the average seasonal snowfall between October and April was 37 inches. During this period, 65 days per season averaged 1 inch or more of snow on the ground, but conditions varied greatly from season to season (MSCO, 2005).

3.1.3 Hydrology

3.1.3.1 Tittabawassee River

The Tittabawassee River is a tributary to the Saginaw River, draining 2,600 square miles of land in the Saginaw River watershed. The Tittabawassee River begins in Roscommon and Ogemaw Counties, which are located approximately 26 miles to the north of Midland and Saginaw Counties. The Tittabawassee

River flows south and southeast for a distance of approximately 80 miles to its confluence with the Shiawassee River approximately 22 miles southeast of Midland. The majority of the Tittabawassee River watershed upstream of Midland is forested or agricultural. The Pine and Chippewa Rivers are tributaries to the Tittabawassee River, and have similar drainage areas and flow contributions to the Tittabawassee River. Together, the Pine and Chippewa Rivers contribute approximately 40 percent of the Tittabawassee flow at Midland (MDNR, 1988).

Upstream of the Midland Plant, river flow is regulated by the Secord, Smallwood, Edenville, and Sanford Dams. The Dow Dam is located adjacent to the Midland Plant. Below the Dow Dam, the river is free flowing to its confluence with the Shiawassee and Saginaw Rivers. Tittabawassee River flow and water level fluctuate daily in response to releases from the Sanford Dam. The average and 100-year flood discharge for the Tittabawassee River based on data from 1937 to 1984 are approximately 1,700 cubic feet per second (cfs) and 45,000 cfs, respectively (Johnson Co., 2001). The term “100-year flood” is a statistical designation that represents a 1-in-100 chance that a flood of this size will occur in any given year (USGS, 1996). The relatively large ratio between the 100-year flood discharge and the long-term average discharge (26.5) indicates that the river is “flashy,” or has a flow regime that is characterized by highly variable flows with a rapid rate of change.

The average monthly discharge from 1937 to 2003 for the Tittabawassee River 2,000 feet downstream of the Dow Dam ranged from approximately 600 cfs (in August) to 3,900 cfs (in March), with an average of 1,700 cfs. Discharge is typically highest in March and April during spring snowmelt and runoff. The maximum recorded historical crest of the Tittabawassee River occurred in 1986. A large storm in September 1986 produced up to 14 inches of rain in 12 hours. The discharge of the river near the Dow Dam reached nearly 40,000 cfs, and the river stage was 10 feet above flood stage at its crest (Deedler, Undated). Flows greater than 20,000 cfs have occurred in 22 of the 95 years between 1910 and 2004, with flows greater than 30,000 cfs occurring in 1912, 1916, 1946, 1948, and 1986. In March 2004, the river discharge reached approximately 24,000 cfs.

The Tittabawassee River floodplain is periodically inundated by floodwaters. Defining the extent of the floodplain for various flood recurrence intervals can be useful in investigating the potential extent of impact caused by deposition of suspended sediments from floodwaters. The extent of the estimated floodplain for flood recurrence intervals ranging from 1 to 500 years was mapped using a Federal Emergency Management Agency (FEMA) hydraulic model and USGS topographic maps. In addition, aerial photographs of the Tittabawassee River from the Midland Plant to the confluence with the Saginaw River were taken during two recent flood events: the March 2004 event (an estimated 8-year event) and the April 2005 event (an estimated 1- to 2-year event). These aerial photos were used to generate a higher-resolution definition of flood extent during more frequent flood events. The extent of the FEMA estimated 100-year floodplain is shown in Figure 3-1.

3.1.3.2 Upper Saginaw River

ATS has performed a limited review and re-analysis of the available environmental data/information on the Upper Saginaw River. Several environmental data collection studies have been conducted in the Saginaw River area since 1980. A detailed discussion of the hydrology of the USR will be included in the USR SAP to be completed in early 2008.

3.1.4 Geomorphology

3.1.4.1 Tittabawassee River

The majority of the Tittabawassee River valley between Midland and Saginaw is characterized by relatively flat floodplains extending to a steep scarp rising to the upland. The upland scarp is the glacial Tittabawassee River channel banks. The river valley has a relatively subdued topographic relief along the length of the river, with water elevations dropping from approximately 595 feet mean sea level (msl) near Midland to 560 feet msl at the confluence with the Saginaw River. The floodplains represent areas of the river valley that are periodically inundated by episodic flooding of the Tittabawassee River. The approximate extent of the 100-year floodplain is shown in Figure 3-1.

The upland areas above the river valley are typically 20 to 30 feet above the valley floor. As the Tittabawassee River approaches the City of Saginaw, the broader valley in the vicinity of Center Road is characterized by gentler slopes away from the river and a broadening of the floodplain.

The Tittabawassee River has moved laterally and incised since glacial times. The river has been relatively stable in its current channel since 1937, the time of the first aerial photographs of the river. The maximum lateral movement in the 6 miles downstream from the confluence with the Chippewa River since 1937 is measured to be approximately 25 feet based on aerial photograph interpretations.

Floodplain and terrace development in the first 3.5 miles downstream of the Chippewa/Tittabawassee confluence is limited by anthropogenic features. The anthropogenic influences in this portion of the river are due to development associated with the City of Midland, Dow Chemical, and Midland Cogeneration Venture (MCV). The next 2.5 miles downstream to the end of the UTR pilot study area is a natural river environment that includes floodplain and terrace development between the river and the upland scarp.

Topographic information was obtained on the Tittabawassee River portion of the Study Area in December 2003 using airborne Light Detection and Ranging (LiDAR) techniques. These data were used to create detailed topographic maps. The Tittabawassee River floodplain can be divided into two general areas based on the morphology of the river valley. The river valley in the northern part of the Study Area is characterized by relatively abrupt valley walls. The valley in the southern part of the Study Area is characterized by gentler slopes away from the river and much broader floodplains.

The Tittabawassee River channel varies from relatively straight upstream of Freeland, to a more sinuous system downstream of Freeland. Although the river exhibits a low-to moderate level of sinuosity throughout, many of the features of a meandering system are present. Sinuosity increases significantly as the river approaches Imerman Park. Typical meandering rivers have a channel that winds back and forth across a river valley. In the river channel, erosion tends to occur on the outsides of river bends, forming cut banks, and deposition tends to occur on the insides of river bends, forming point bars. The Tittabawassee River has a number of these features and yet the anthropogenic features (including extensive sheet pile along the river bank, steep constructed banks along both the Midland Plant and MCV Plant and cooling ponds, rip-rap armoring at several locations, a major bridge, and the Dow Dam) have inhibited the natural development along the upper reaches of the river by constraining the lateral movement of the river channel and containing the flood flows. Depositional features commonly present on floodplains downstream of this area include levees, splays, and overbank deposits. Levees form along river banks where floodwaters overtop the banks and deposit coarse-grained material. Overbank deposits are found in low-lying areas of the floodplain where fine materials settle out of suspension following floods.

The Tittabawassee River is a high-energy system that undergoes a rapid increase in flow in response to periods of precipitation, as indicated by a high ratio of the flood discharge to long-term average discharge. Analyses of in-river sediments indicate that they are composed of approximately 87 percent medium/fine sand. Areas of surficial fine-grained sediments (that is, silt or clay) that might be an indication of low-energy depositional areas were not encountered in poling and coring studies conducted in 2003 and 2004. This strong response to precipitation also results in overtopping of the riverbanks during larger flow events, and may contribute to ongoing erosion and deposition on and adjacent to the riverbanks under a range of flow rates.

The 2005 TR Scoping Study (CH2M Hill, 2005a) included a general reconnaissance of physical conditions and geomorphic features in the areas sampled. Because hydrodynamic conditions influence development of geomorphic features along the river and on the floodplain, different grain size distributions are present in the geomorphic features. Relatively coarser-grained deposits are typically observed in features adjacent to the river formed by lateral accretion under higher velocity flow regimes (for example, point bars). Finer-grained materials are typically located at greater distances from the river channel and represent vertical accretion under low velocity flow regimes (for example, overbank deposits).

3.1.4.2 Upper Saginaw River

The Upper Saginaw River channel is a relatively lower energy river, with a width that varies from approximately 375 feet wide in the meander immediately downstream of the confluence with Tittabawassee River, to 800 feet wide in the turning basins. The Upper Saginaw channel water depths range from 0.1 foot on the shoreline to 22 feet in the center of the channel upstream of the I-675 bridge. The channel of the Upper Saginaw River is a relatively straight channel, with most of its banks between the confluence of the Shiawassee and Tittabawassee Rivers and the Sixth Street turning basin armored with various types of riprap, gabions and sheetpile.

As discussed above, ATS has performed a limited review and re-analysis of the available environmental data/information on the Upper Saginaw River. Several environmental data collection studies have been conducted in the Saginaw River area since 1980. The objective of these studies varied, ranging from general contaminant and sediment characterization to preliminary human health and ecological risk assessments. The available sources of suitable geomorphic information and a detailed discussion of the geomorphology of the USR will be presented in the USR SAP in early 2008.

3.1.5 Anthropogenic Influences

Human activities have modified the Tittabawassee and Saginaw Rivers prior to and during the Midland Plant production operations. These activities range from broad changes in the watershed that affected the hydrology of the entire river system to localized changes along the bank of the river that affect deposition and erosion within a specific area. This section summarizes the major anthropogenic activities that have influenced the Tittabawassee River over the first six miles downstream of the confluence with the Chippewa River based on the *GeoMorph®* investigation work conducted on the UTR in 2006. Anthropogenic influences on the remainder of the TR and the USR will be evaluated during the *GeoMorph®* investigations planned for 2007 and 2008.

3.1.5.1 Logging and Salt Manufacturing Prior to The Dow Chemical Company's Operations

Prior to the production of chemicals at The Dow Chemical Company, logging activities created substantial adverse impacts on the watershed, the hydrology of the river and the floodplain ecology. In the early 1800's, the headwaters of the Tittabawassee River, north of Midland, and the area around the first six miles downstream of the confluence of the Chippewa River with the Tittabawassee River were dominantly forested with Hemlock, White Pine, and Sugar Maple. (MNFI, 1998). This forest was logged intensively beginning in about 1847 up through the late 1800's. Saw logs were rafted down the Tittabawassee River system to mills in Saginaw, where much of the wood was "wasted" into the local environment due to wide saw blades in the early years and defects in the lumber. In later years, saw widths were reduced and the slab wood and reject boards were processed into wood lath, roofing shingles, cedar blocks and other commercial products, with a large volume of the sawmill wastes also being burned to supply power to the sawmills and to the brine mining/salt making operations that developed to take advantage of this excess fuel supply and the readily available brine underlying the area.

During this period, logging and major forest fires removed vegetation across most of the watershed and sterilized much of the soil, significantly changing the hydrology and erosion and sedimentation patterns in the Tittabawassee and Saginaw River watersheds through increased runoff and decreased baseflow. The first major "shore to shore" forest fire occurred in 1871, followed by lesser fires throughout the 1870's and 1880's. A large storm combined with the denuded watershed created unprecedented flooding in Midland and Saginaw in 1886.

In addition to the change in vegetation, the Tittabawassee River was used to raft logs to milling operations along the Tittabawassee and Saginaw Rivers. Occasionally log jams would occur that significantly impacted river flow, erosion, deposition, and aquatic and riparian habitat. In 1873, a log jam on the Tittabawassee River was reported to have been two to five logs deep and extended up river approximately 130 miles. Activities were taken to manage and remove these log jams, including clearing the river channel and dynamiting the jams. Log rafting and the preparation of the river for log rafting significantly affected habitat along the river by altering the course and hydrodynamics of the river channel. In addition, the presence of the logs in the river and the subsequent log jams led to significant scouring in the river and altered the hydraulics. (AIM, undated)

Lumber production from the Saginaw River peaked at over one billion board feet of lumber being produced from 70 mills in 1882. The Tittabawassee Boom Company was formed to move the lumber down the Tittabawassee River, and rafted 11,800,000,000 board feet of logs down the Tittabawassee River system prior to going out of business in 1894 (AIM, undated).

Wells were installed in the area that produced brine from underground formations. The scrap wood from the milling operations was used as an economic source of heat to evaporate the brine and form salt. Salt production was integrated into most of the mills, and it is estimated that ¼ of the wage earners in the mills around Saginaw worked producing salt. Michigan became a major producer of salt, and by 1883 accounted for one half of the salt production in the United Sates (AIM, undated).

Waste materials from the logging and salt production were often discharged into the river system. In addition to the scrap wood and saw dust, the salt production operations released residual brine with other minerals that may have contained common inorganic salts such as calcium and magnesium carbonate and magnesium hydroxides. Iron was also present in the lime and gave the salt a reddish color if not removed. To eliminate the red tint in the salt, the brine was treated to precipitate out the iron, and the removed solids were also wasted out of the system (AIM, undated).

The log rafting on the Tittabawassee River ended prior to the end of the 19th century, and the Tittabawassee Boom Company went out of business in 1894. The mills in Saginaw continued to cut wood imported from as far away as Canada, but these operations were also in decline at the start of the 20th century. While the waste wood was no longer available as cheap fuel for evaporating brine, salt production in Michigan continued into the 1900's, and Michigan was still among the leading producers of salt in 1911 (JIEC, 1911).

3.1.5.2 Dams

Dams have been placed across the Tittabawassee River to control flow and to harness the flowing water. These dams significantly affect the hydrology and hydraulics of the Tittabawassee River.

During the logging period, dams were built to control the flow of water during log rafting periods. In 1866, dams were built on the Salt and Chippewa Rivers by the Tittabawassee Boom Company (AIM, undated).

The Sanford, Edenville, Smallwood, and Secord dams were constructed on the Tittabawassee River in 1925 to provide hydroelectric power. The Sanford Dam is the last dam in the sequence up river from Midland and has the largest impact on river flows in the Tittabawassee River downriver from Midland. The Sanford Dam is used to generate power during peak periods of the day, and the turbine is typically run for 7 hours per day, five days per week (AIM, 2006).

This series of historic upstream dams continues to control the flow along the Tittabawassee River near the Midland Plant under normal flow conditions. During peak flow periods, these dams retain a portion of flood flows and aid in reducing the frequency of downstream peak flows. During lower flow periods, the Sanford Dam (the southern dam and most downstream in the series) discharges 210 cubic feet per second, which is the minimal flow maintained in the Tittabawassee River except under severe drought conditions (AIM, 2006).

The present daily schedule for hydroelectric turbine operations at the Sanford Dam leads to diurnal fluctuations in the river level at Midland. These fluctuations can typically be observed in the river stage measurements at the USGS gauging station in Midland, Michigan. The engineers and scientists presently involved in the UTR characterization study suspect that this diurnal fluctuation of river water level may be causing undercutting and accelerated erosion in cut banks by repeatedly saturating and then draining the soils at the waters edge and thereby making these soils more susceptible to erosive forces during small to medium size storm events. Further study of this apparent undercutting process will be conducted during the RI work in 2007 and 2008 to determine whether this apparent undercutting adversely affects the stability of cut banks along natural levees having elevated concentrations of COI.

A dam was installed within the plant area at the Midland Plant before 1945 to provide sufficient water depth behind the dam to supply a reliable flow of water to Dow for process operations.

3.1.5.3 Berms

The floodplain of the Tittabawassee River has been narrowed through the first few miles downstream of the confluence with the Chippewa River through the construction of a series of berms. These berms extend over thousands of feet along the river and border ponds and fill areas adjacent to the river. The series of berms reduces the floodway of the Tittabawassee River over approximately a three mile stretch from Station 30+00 through Station 210+00. Within parts of this section, the constructed berms have reduced the width of the floodplain from approximately 5,000 feet across prior to the berm construction to a current width of approximately 500 feet across. This reduction in the width of the floodplain affects the hydrology of the river during flood events by restricting the cross-sectional area of the floodway, thereby increasing flow velocities, and by reducing the amount of overbank storage available during a storm. The following berms are present in the upper section of the Study Area:

- The berm for the ash pond extends approximately 1,300 feet along the southwest side of the Tittabawassee River north of the Dow Dam, from Station 30+00 through Station 46+00. Based on a review of historical aerial photographs, this berm was not present in 1945 and was completed by 1956; it is still present today.

- The brine pond berm extends approximately 4,500 feet along the southwest side of the river south of the Dow Dam, from Station 70+00 through Station 115+00. This berm was constructed before 1938. A series of ponds and a filled area are present behind this berm, including the No. 6 Brine Pond which is used for storage of spent brine, and the Tertiary Pond system which is used for polishing of treated wastewater. Bullock Creek was re-routed when this berm was created. Bullock Creek currently enters the Tittabawassee River at the south end of this berm, while the original channel of Bullock Creek is now occupied by the T-Pond.

- Farther south on the southwest side of the Tittabawassee River, the berm for the MCV cooling pond extends for approximately 8,000 feet from Station 130+00 through Station 210+00. Based on historical aerial photograph review, the cooling pond was constructed beginning in the early 1970's and was completed by 1972. This berm is still present and maintained today.

- On the northeast side of the Tittabawassee River, a long berm now borders a Dow fill area that extends along 8,800 feet of the river from Station 70+00 to 158+00. The berm was constructed some time prior to 1938 and currently borders a series of fill areas along the northeast bank of the river.

3.1.5.4 Sheet Piling

Sheet piling has been used to stabilize the banks of the Tittabawassee River along numerous stretches within the Midland Plant area and in several downstream locations. This type of bank stabilization increases channel velocity in the immediate area during flood stage by restricting the cross-sectional area of the river and, depending on the local cross-section, may increase downstream flood elevations and erosive forces by increasing the flows and velocities of water that can no longer be stored on the overbank above the stabilized banks.

The northeast edge of the river is contained by sheet pile through the entire plant area for approximately 2 miles, from Station 25+00 through Station 158+00. This sequence of sheet pile is part of the revetment groundwater interception system (RGIS) that is used to intercept the flow of groundwater from the plant flowing toward the Tittabawassee River by reversing the hydraulic gradient along the river. Within this area, approximately 1,700 feet has a second sheet pile located farther into the former river channel to stabilize a sand bar deposit (Station 121+00 through Station 138+00). The RGIS was installed through a series of construction stages and improvements starting in 1979 and was largely completed by 1987.

Upgrades, improvements and maintenance of the system has continued to the present through the addition of purge wells, improved drain tiles and system repairs and cleaning. One section of the RGIS underdrain system was recently repaired, and notice has recently been given to MDEQ of one other section that will likely require repair and/or cleaning in the near future. Typical cross sections details of the sheet piling and underdrain design are shown on Figure 3-2.

Sheet pile was also installed around the current location of the Dow Dam prior to and related to the Dam. The rectangular embayment on the west side of the river just north of the Dow Dam was present in 1938 prior to the installation of the Dow Dam, and there was sheet piling present north of the Dow Dam leading up to the dam as early as 1945. Sheet piling is also present in front of the MCV facility near Station 130+00 on the southwest side of the river.

3.1.5.5 Bridges

A series of bridges has also been constructed across the Tittabawassee River within the RIWP Study Area. These bridges affect the flow direction and velocities around the supports and also around the approach ramps constructed for the bridges. Some of these bridges significantly constrict flow through a narrow channel during flood events (e.g. the Gordonville Road Bridge) creating orifice effects that increase erosional turbulent eddy currents below the bridges and backwater effects upstream. The following bridges are or have been present in the Upper Tittabawassee Study Area:

Bridge	Station	Constructed	Status
Tridge (walking bridge)	0+00	1981	Still present
Benson Street Bridge	11+00	Prior to 1938	Removed approximately 1967
Poseyville Road Bridge	18+00	1967 - 1968	Still present
Dow Rail Pipe Bridge	50+00	1959	Still present
Dow Rail Bridge	52+00	1929	Still present
Pipe Bridge	114+00	1973 - 1979	Still present
Consumers Rail Bridge	164+00	1970	Still present
Gordonville Road Bridge	233+00	1976	Still present
Smith’s Crossing	261+50	Prior to 1938	Closed but still present

An assessment of the effects of these bridges on the depositional and erosional patterns in the UTR will be presented in the UTR *GeoMorph*® site characterization report to be submitted in February 2007.

For the lower Tittabawassee River and Upper Saginaw Rivers, an inventory and assessment of the effects of bridges, utility crossings, shoreline armoring and other anthropogenic features will be performed during the *GeoMorph*® site characterization investigations planned in 2007 and 2008, and will be presented in the December 2008 RI Report.

3.1.5.6 Pipe Crossings in the Upper Tittabawassee River

The pipeline from the wastewater treatment plant to the Tertiary Pond system presently passes overhead on the pipe bridge. A series of pipes were historically laid beneath the Tittabawassee River to connect the southwest and northeast sides of Dow's Midland plant. To the best of The Dow Chemical Company's knowledge, these pipes have been abandoned and plugged. The installation of these pipes likely disturbed the bottom of the Tittabawassee River channel and may have had transitory effects on sediment load in the river.

3.1.5.7 Discharges into the Tittabawassee River Watershed

Direct discharges to surface waters within the Tittabawassee River watershed have been and continue to be a part of the anthropogenic influences on the watershed. There are a number of cities that lie completely within the Tittabawassee River watershed and discharge their treated wastewater effluent into the river system, including Midland, Mt. Pleasant, Alma, and Clare, Michigan. In addition, there are a number of industrial facilities within the watershed of the Tittabawassee River that currently have or have had discharges to the Tittabawassee River. These industrial facilities include Dow Chemical in Midland, Dow Corning in Midland, Velsicol Chemical in St. Louis, and Total Petroleum in Alma.

Dow Chemical has discharged wastewater into the Tittabawassee River since the early years of its operations, and continues to discharge wastewater treated through their on-site wastewater treatment plant and an NPDES permitted outfall. During the preparation of this RIWP, historical discharge locations have been identified from previous NPDES permits and historical aerial photographs.

A copy of the draft Special Conditions for The Dow Chemical Company's 1973 NPDES Permit (# MI 070 0X5 2 710109) documents the historical presence of 11 discharge points. These discharge points were labeled 1 through 6 and 11 through 15. Brief descriptions and approximate river-station location references for the outfalls are presented in Table 3-1. Nine of the 11 outfalls discharged into the Tittabawassee River; the remaining two outfalls discharged into Lingle Drain. Of the nine outfalls that discharged directly into the Tittabawassee River, seven can be observed on historic aerial photographs.

Table 3-1 1973 NPDES Permit Special Conditions Outfalls

Outfall No. (1973 Permit)	Description (1973 Permit)	Flow (MGD) (1973 Permit)	Station	Side of River
1	WWTP	46	128+00	NE
2	54" CWS	6	Lingle	NE
3	60" CWS	27.4	81+00	NE
4	84" CWS	3.5	Lingle	NE
5	Asby Ditch	1	30+00	SW
6	24" WSS	1	61+50	SW
11	E fl-60"	42.8	46+00	NE
12	H fl-96"	30	61+00	SW
13	12"ST-47 Bldg	0.144	27+00	NE
14	8"CI-47 Bldg	0.432	29+00	NE
15	8"ST-47 Bldg	0.27	31+00	NE

During the preparation of this RIWP, an additional nine outfalls have been observed on aerial photographs of the Tittabawassee River between its confluence with the Chippewa River and the confluence with Lingle Drain. These are presented in Table 3-2.

Table 3-2 Additional Outfalls Observed in Aerial Photographs

Station	Side of River
20+00	NE
24+00	NE
34+05	NE
36+00	NE
42+00	NE
58+00	NE
58+00	SW
71+00	NE
106+00	SW

A figure showing the location of these outfalls will be included in the February 1, 2007 UTR *GeoMorph®* Site Characterization Report

3.1.6 Sediment Characteristics

In late 2003, sediment probing and coring work was conducted along regularly spaced transects within the Study Area to characterize the composition and thickness of unconsolidated sediments in the Tittabawassee River (LTI, 2004b). Additional sediment core information was collected as part of the Scoping Study (CH2M Hill, 2005c). In addition, surface (0 to 4 inches) and subsurface (8 to 12 inches) samples from selected cores were analyzed for grain-size distribution, total organic carbon (TOC) content, and bulk density. The thickness of unconsolidated sediments in the riverbed ranged from 0 to greater than 12 feet, and typically was between 1.5 and 7.5 feet. The thickness of unconsolidated sediment was related to the morphology of the river. Unconsolidated sediments were thin or absent on the outside of bends where water depths were the greatest. Along straight sections of the river, the sediment thickness and water depths were more uniform.

Visual characterization of the sediment cores indicated that sand was the dominant sediment type throughout the river, particularly in surficial sediments. The survey did not identify any areas of surficial fine-grained sediments (that is, silt or clay) that might indicate low-energy depositional areas. Fine-grained sediments were found underlying sandy surface sediments at approximately 20 percent of the surveyed locations. Wood and other organic material were found in some cores. Sediment samples were composed primarily of medium and fine sand with a median TOC content of approximately 1 percent. The median silt and clay content was 5 percent. The sediment composition data indicate that the Tittabawassee River is a relatively high-energy system; that is, sufficient energy is available to transport fine-grained materials downstream. The sediment characteristics are directly affected by the periodic release of water from the Sanford Dam.

From August through December, 2006, a sediment probe and coring investigation was conducted on the first 6 miles of the Tittabawassee River; from the confluence of the Chippewa and Tittabawassee Rivers to approximately 1½ miles downstream of the Smith's Crossing Bridge. The sediment sampling locations were selected to characterize the 15 river reaches mapped in the first 6 miles. Each river reach was selected based on similar geomorphic features.

The sediment in each river reach was characterized using between six and twelve sample locations based on the length of the reach and the sinuosity of the river within that reach. The sample locations were placed in transects perpendicular to the flow of the river with 3 sample locations per transect.

The sediment thickness ranged from 0 feet to 5 feet in the Tittabawassee River channel. The in-channel depositional pattern is typical for river channels. The sediment thickness is fairly uniform across the channel in straight reaches of the river. The thickest sediment is found on the inside of meander bends and the thickness of sediment decreases towards the outside of the meander bend.

The sediment composition is predominantly sands ranging from very fine sand to coarse sand. The sands are primarily well sorted which is typical in a river setting. The poorly sorted material is associated with sand bar areas. Fine grained sediment is found in limited amounts associated with the sands. The sediment that has the greatest percentage of fine grained material is found in the off-channel areas that are connected to the river but are not affected by the river's base flow. Wood and wood-like material is found in a majority of the sediment profiles. This material is typically found in the middle of the sediment profile and is often found in specific layers.

3.1.7 Sediment Transport

Soil and sediment transport processes include in-river solids transport through the water column, erosion and deposition of solids in the floodplain, and exchange between the river channel and floodplain under flood conditions. These processes are described in greater detail below based on recent work on the Tittabawassee River.

3.1.7.1 In-River Solids Transport

Solid particles may be transported in the water column as suspended solids or as bedload along the river bottom. Suspended solids are generally fine-grained materials such as silt and clay that may be transported considerable distances once suspended. Larger particles (coarser sand and gravel) generally move along the bottom of the river as bedload, traveling for relatively shorter distances on a per-event basis. The movement of larger particles depends on the water velocity and therefore such particles may move largely during high-energy flood events. Finer sands may move either in suspension or as bed load.

On average, the Tittabawassee River has a suspended solids concentration of 30 milligrams per liter (mg/L), which is consistent with suspended solids concentrations in other tributaries of the Saginaw River (MDNR, 1988; MDNR, 1994). Concentrations as high as 85 mg/L have been observed during and after heavy precipitation events (LTI, 2004a). In October 2003, flow and solids monitoring of the river was initiated to improve the understanding of erosion, transport, and deposition throughout the river system (LTI, 2004a). These data provide a preliminary indication of solids transport (and therefore adsorbed COIs) through the system and allow construction of a preliminary conceptual model of solids transport. Preliminary results indicate that most of the solids transported through the river originate in the watershed upstream of Midland. In the three high flow events measured in 2003-2004 and a smaller event observed in March/April 2005, no discernable net gain or loss of suspended solids load occurred between the Midland Plant and the confluence of the Tittabawassee and Shiawassee Rivers.

The sediment bed may be episodically affected by scour induced by winter ice formation and breakup. The Tittabawassee River typically experiences significant ice formation during the winter months, with periodic ice breakup during mid-winter thaws that elevate river flows. Ice breakup and movement might affect the sediment bed in several ways: by individual ice floes impacting the sediment bed, banks, and near-bank areas; by the formation of ice jams; and by the enhanced scour that can occur as river flow is diverted around or under ice jams. Ice jams can also cause overbank flooding and sediment deposition. All of these factors may affect the stability of the sediment bed and bank areas on the Tittabawassee River.

3.1.7.2 Floodplain Erosion and Deposition Processes

The majority of erosion and deposition is episodic in nature; consequently, sediment and floodplain soil movement is believed to occur primarily during periodic flood events. The amount or rate of erosion and deposition is dependent on the intensity of the flood event, with large events resulting in correspondingly larger amounts of floodplain soil and sediment movement. Higher flow events result in increased erosion and transport for two reasons: first, the increased shear stress exerted on surficial soils or sediments increases the rate of erosion, and second, the increased flow energy has a correspondingly greater capacity to move solids downstream by keeping them in suspension.

Pilot studies were conducted to evaluate the potential effectiveness of radiological age dating (geochronology) and dendrogeomorphic techniques to evaluate net rates of floodplain soil deposition at various representative locations in the floodplain. Dendrogeomorphology consists of the measurement of soil accumulation above the root systems of trees. Geochronology relies on the evaluation of the relative abundance of naturally occurring and man-made radioactive elements in the soil column. These methods are complementary, providing multiple lines of evidence. The results of these studies are provided in the pilot study reports (LTI, 2005a; LTI, 2005b).

The dendrogeomorphology and geochronology results indicate that soil accretion rates along the Tittabawassee River floodplain are on the order of 0.1 to 0.5 inches per year with an average of 0.17 inches per year, which equates to a range of approximately 1 to 4 feet of soil accumulation over the past 100 years. The geochronologic and dendrogeomorphic results are in close agreement. Accretion rates vary locally, and preliminary analyses suggest that they appear to be influenced by local geomorphic features, including topography, proximity to the river, and channeling.

The accretion rates described above are net rates, reflecting the results of erosion and deposition operating over many years. While the measurements to date show net accretion in the floodplain, it is likely that localized erosion has also occurred. For example, after the March 2004 flood event, recently eroded areas were visually apparent such as scour around fence posts, downstream of trees, and around other obstructions to flow. However, available measurements suggest a general tendency of the floodplain to gain solids rather than lose them, and localized scour likely results primarily in local redistribution of soils and limited export from the floodplain.

Available measurements of solids loads to date are limited. Observations of solids transport in the river under flood events in 2003 and 2004 showed that the in-river solids loads measured at the upstream and downstream ends of the study area were not sufficiently different to indicate a clear gain or loss of load across the study area. This is consistent with observations of relatively slow floodplain accretion described above.

Bank undercutting, overhanging vegetation and lateral retreat can be observed at a number of locations between Midland and the Saginaw River confluence. The steep banks and ongoing lateral retreat are a product of several factors, including: the post-glacial rebound of the land surface in mid-Michigan and subsequent incising of the river; the "flashiness" of the river as evidenced by the high peak to average discharge ratio; and likely historical increases in peak discharge caused by land development changes in the watershed, including extensive logging in the 19th century.

Human activities have disrupted the natural fluvial system through the construction of various structures and the creation of cut-and-fill areas. These features alter river flow patterns, restricting erosion and deposition in some areas while causing erosion and deposition in others. Examples of man-made features that affect the natural fluvial system include bridges, elevated roadways, and railroads where fill was used to elevate them above the floodplain; other areas that were filled to elevate the land surface above the floodplain; erosion control features used to stabilize riverbanks, dams, and cut areas where floodplain materials were removed; hydrologic inputs from surface water discharge, water releases from dams and power plants; and agriculture fields where ridges are leveled and depressions filled over the years by plowing and tilling.

3.1.7.3 River-Floodplain Exchange

As described above, measurements of in-river suspended sediment load and floodplain accretion in the Tittabawassee River valley show (1) a significant load of suspended solids that is transported by the river, primarily under high flow conditions, and (2) positive rates of accretion in the adjacent floodplain over time that suggest flood-driven net solids movement from the river to the floodplain. The process by which flow and solids pass from the river channel to the floodplain during the rise, peak, and recession of a typical flood event is complex and depends on many factors, including the magnitude of flow, the bathymetry of the river and topography of the floodplain, the amount of vegetation in the floodplain and its tendency to slow down the flow, and the characteristics of the solid particles themselves, including density, cohesiveness, particle size, and tendency to settle.

A study of floodplain, bank, and sediment bed elevation changes was conducted between November 2004 and November/December 2005, to observe erosion and accretion of solids during this time period. Elevations were surveyed at fixed stations along transects aligned perpendicular to the Tittabawassee River, spanning the river from bank to bank and including adjacent shoreline and upland floodplain areas. Three parallel transects were surveyed in each of three locations, including Dow property near River Mile 17.5 (RM 17.5, indicating a location 17.5 miles upstream of the confluence with the Shiawassee River); Imerman Park; and downstream of Center Road at the Shiawassee National Wildlife Refuge. Each transect location included steep banks separating the river from the upland floodplain. Additional details of locations and methods are discussed in Attachment C.

In general, the greatest measured changes between the two survey rounds were in sediment bed elevations. These ranged in magnitude from a localized decrease of 2.0 feet, at a mid-channel station along one of the RM 17.5 transects, to increases as large as 1.8 feet within 50-75 feet of the bank at Imerman Park. In general, more sediment bed stations were characterized by elevation decreases than increases.

Measured bank elevation changes fell within a narrower range, from an increase of 1.1 feet at the top of the bank along one of the Imerman Park transects, to a decrease of 1.1 feet near water's edge along another of the Imerman Park transects. In general, more bank stations were characterized by elevation increases than decreases.

Measured upland floodplain elevation changes fell within the narrowest range, from an increase as high as 0.3 feet along one of the RM 17.5 transects to a decrease of 0.4 feet along another of the RM 17.5 transects. In general, more upland floodplain stations were characterized by elevation increases than decreases.

These estimates of elevation change over a single year at three locations generally support the observation that banks and floodplains were areas of net solids accretion. Sources of uncertainty common to the river, bank, and floodplain elevation changes measured in this study include the vertical and horizontal error components inherent in the elevation surveys, plus natural factors including leaf accumulation and frost heave. Cumulative elevation changes of larger magnitude that may occur over longer time periods could be estimated by repeat surveys at the same locations, without a commensurate increase in uncertainty of the estimates. Follow-up surveys may be conducted once the ongoing *GeoMorph*® pilot study has identified the erosion and deposition zones in the UTR, and established the floodplain accretion patterns.

3.1.8 Land Development

Residential, commercial, and industrial development within the Tittabawassee River floodplain is limited because of periodic historic flooding. Current land development was evaluated within the floodplain and assigned to one of six categories similar to those used by the MDEQ for establishing generic cleanup criteria. The total acreage in each land development type in the FEMA estimated 100-year floodplain is summarized below. Land development classifications were established primarily by reviewing aerial photographs and using secondary information such as zoning and knowledge of local conditions. Land development is summarized in Attachment D.

The following land development categories were defined:

- **Recreational/Undeveloped.** This category designates properties intended for regular outdoor recreational activities and/or property that is primarily in a natural state. Lands included in this category are developed parks, boat launches, picnic areas, athletic fields, golf courses, country clubs, shooting clubs, undeveloped private property, undeveloped parkland, and wildlife areas. (Total Acres = 4,500; Percent of Area = 57)
- **Agricultural.** This category is used for lands that are actively used for farming, including cropland, orchards, and grazing. (Total Acres = 1,700; Percent of Area = 22)
- **Residential.** This category includes all lands that are used predominately for residential purposes. These include single-family homes, condominiums, apartment buildings, and mobile homes. (Total Acres = 1,200; Percent of Area = 16)
- **Industrial.** This category is used for properties that contain manufacturing and other industrial facilities. Land is generally highly reworked and little surface soil is typically present. Examples of industrial land development include manufacturing facilities, power plants, and municipal wastewater treatment facilities. Waste disposal sites, such as open or closed landfills, were also included in this category. (Total Acres = 320; Percent of Area = 4.0)
- **Commercial I.** This category includes commercial or other properties that are commonly occupied by sensitive populations. This land development category includes schools, nursing homes, and hospitals. (Total Acres = 9.2; Percent of Area = 0.1)

- **Commercial II, III, and IV.** This category includes the MDEQ classifications for all other types of commercial properties, such as office buildings, retail, restaurants, banks, gas stations, car dealerships, and automotive repair shops. Land used for these purposes was combined into a single category for this evaluation. (Total Acres = 120; Percent of Area = 0.1)

The dominant type of land development in the Tittabawassee River floodplain is Recreational/ Undeveloped, which accounts for 57 percent of the FEMA estimated 100-year Floodplain area. These lands include a substantial amount of undeveloped private property and encompass a portion of the Shiawassee National Wildlife Refuge. Agricultural lands are the next largest land development category and account for approximately 20 percent of the FEMA estimated 100-year floodplain. Agricultural areas are typically found in the lower portions of the floodplain and are susceptible to flooding. Residential land development accounts for approximately 15 percent of the FEMA estimated 100-year floodplain. Residential structures are generally located at higher elevations, in areas that are less frequently flooded.

Local zoning ordinances indicate current and intended future land uses. In accordance with Part 201 regulations, application of cleanup criteria must be consistent with land use. Information has been compiled on land use and zoning in the Study Area. Each municipality establishes numerous zoning categories to meet local needs. To gain a general understanding of zoning in the Study Area, zoning was consolidated into five broad categories: agricultural, commercial, industrial, residential, and natural areas. Zoning was found to be generally consistent with the actual land development category in the Tittabawassee River floodplain.

Four of the eight political entities responsible for land development planning in the Tittabawassee River Study Area have created the following zoning categories intended to minimize the impacts of flooding and preserve the natural condition of the floodplain:

- Thomas Township: E-1 = Environmental Areas
- Tittabawassee Township: G-C = Greenbelt Conservation Floodplain
- James Township: FC-1 = Floodplain Consideration
- Saginaw Township: FC-1 = Floodplain Consideration

A similar evaluation of land development for the Upper Saginaw River will be conducted in 2007.

3.1.9 Water Body Use

Historically the Tittabawassee River has been used for a variety of industrial and recreational activities, including bank fishing. However, its shallow depth (generally between 3 to 11 feet) precludes use by watercraft other than small shallow-draft boats. Recreational fishing in the river below Midland is guided by a fish consumption advisory issued by the Michigan Department of Community Health, as updated (MDCH, 2004a; MDCH, 2004b).

3.1.10 Ecology

The Tittabawassee River and floodplain lie within the northern hardwood region of the Eastern Deciduous Forest. The floodplain is located within the Saginaw Bay Lake Plain Regional Landscape Ecosystem, as established by the USGS (Albert, 1995). This regional landscape ecosystem is characterized by the prevalence of both upland and palustrine (wetland) native plant communities, including forests, swamps, marshes, and scattered prairies. Historically, fire, flooding, and wind are identified as the dominant disturbance regimes (Cohen, 2004).

The vast majority of native forests originally present in Saginaw and Midland Counties has been converted to anthropogenic uses (Albert, 1995). The largest remaining contiguous forest is located within the Shiawassee National Wildlife Refuge, which contains approximately 3,500 acres of forest (USFWS, 2001). The remaining forest patches within the Tittabawassee River floodplain are also generally in a mid-successional state (that is, in the mid-stage of growth following a natural disturbance). Using the Michigan Natural Features Inventory (MNFI) Community Classifications (Cohen, 2004), they can be classified as mesic northern forests. This broadly defined category is characterized by numerous regional, physiographic, and soil type variations; along with a varying dominance of conifers and hardwoods. Considering the species present at the Shiawassee National Wildlife Refuge, it is apparent that lowland and upland hardwood stands are dominant in the Tittabawassee floodplain. The Refuge's Comprehensive Conservation Plan identifies maple, oak, hickory, ash, willow, elm, and cottonwoods (USFWS, 2001). Hardwood stands within the mesic northern forest tend to have a defined shrub layer and a very diverse herb layer (Cohen, 2004). Shrub species generally present in mesic northern forest include striped maple *(Acer pennsylvanicum)*, mountain maple *(Acer spicatum)*, alternate-leaved dogwood *(Cornus alternifolia)*, beaked hazelnut *(Corylus cornuta)*, leatherwood *(Dirca palustris)*, fly honeysuckle *(Lonicera canadensis)*, wild gooseberry *(Ribes cynosbati)*, red elderberry *(Sambucus pubens)*, Canada yew *(Taxus canadensis)*, and maple-leaf viburnum *(Viburnum acerifolium)*. Herbaceous plants generally present in mesic northern forest include various baneberry *(Actaea)*, trillium *(Trillium)* and sedge *(Carex)* species, jack-in-the-pulpit *(Arisaema triphyllum)*, bunchberry *(Cornus canadensis)*, Solomon's seal *(Polygonatum pubescnes)*, star flower *(Trientalis borealis)* and an array of ferns and mosses. Also found in this forest type is the presence of chlorophyll-free seed plants such as Indian pipes *(Monotropa)*, coral root *(Corallorhiza)*, and beech drops *(Epifagus virginiana)*.

Because the area of interest lies within a floodplain, wetlands are a common climax community. Forested wetlands are consistent with MNFI's southern floodplain forest community. Dominant species of this community type include sugar maple, green ash *(Fraxinus pennsylvanica)*, red maple *(Acer rubrum)*, butternut *(Juglans cinerea)*, black maple *(Acer nigra)*, Ohio buckeye *(Aesculus glabra)*, box elder *(Acer nigundo)*, black ash *(Fraxinus nigra)*, black willow *(Salix nigra)*, and white poplar *(Populus deltoides)* (MNFI, 2003).

A review of National Wetlands Inventory maps identifies several classes of wetlands present within or near the Tittabawassee River floodplain, including emergent, forested, and scrub-shrub wetlands. Such communities have also been identified within the Shiawassee National Wildlife Refuge (USFWS, 2001).

The wildlife present within the Tittabawassee River floodplain is typical of that supported by the remaining natural forest and wetland communities. Despite the habitat fragmentation along the river, a diverse animal population is present. Resident game species include white-tail deer *(Odocoileus virginianus)*, ring-necked pheasant *(Phasianus colchicus)*, and wild turkey *(Meleagris gallopavo)*. Fur-bearers that are readily observed in the area include beaver *(Castor canadensis)*, muskrat *(Ondatra zibethica)*, mink *(Mustela vison)*, ground hog *(Marmota monax)*, and raccoon *(Procyon lotor)*. Birds include the belted king fisher *(Ceryle alcyon)*, great blue heron *(Ardea herodias)*, mallard duck *(Anas platyrhynchos)*, bank swallows *(Riparia riparia)*, American robin *(Turdus migratorius)*, great horned owl *(Bubo virginianus),* least sandpiper *(Calidris minutilla)*, blue jay *(Cyanocitta cristata),* red tail hawk *(Buteo jamaicensis)*, turkey vulture *(Cathartes aura)*, red-headed woodpecker *(Melanerpes erythrocephalus)* and Baltimore oriole *(Icterus galbula)* (Peters, 2001). The Shiawassee National Wildlife Refuge reports that 237 bird species, 9 reptile species, 9 amphibian species, 36 fish species, and 27 mammal species can be observed at the refuge throughout the year (Peters, 2001). Creel surveys conducted by Michigan Department of Natural Resources (MDNR) from 1999 to 2002 indicated that 14 different species of fish were taken from the Tittabawassee River by anglers (USDHHS, 2005). Walleye is the most commonly harvested fish. More recent data generated by Michigan Department of Community Health (MDCH) confirms the presence of an extensive fisheries resource in the Study Area.

According to the MNFI, two species listed as threatened under the federal Endangered Species Act and one candidate species for listing might occur in proximity to the area. The bald eagle *(Haliaeetus leucocephalus)* is a federally threatened species that might inhabit areas of both Saginaw and Midland Counties. Bald eagles typically nest near coastal areas, rivers, or lakes. The prairie fringed orchid is also listed as a federally threatened species, occurring in bogs and wet prairies in Saginaw County. The eastern massasauga rattlesnake *(Sistrurus catenatus catenatus)* is federally listed as a candidate species. It can be found in bogs, wet meadows, and floodplain forests in Saginaw County (MNFI, 1999)

In addition to the species listed above, the MDNR has listed nine animal species and six plant species in Midland or Saginaw counties as endangered or threatened under state law. The presence of appropriate habitat for these species within the Tittabawassee River and Floodplain study area has not been demonstrated. The animal species include the red-shouldered hawk *(Buteo lineatus)*, common loon *(Gavia immer)*, common tern (*Sterna hirundo),* king rail *(Rallus elegans)*, snuffbox mussel *(Epioblasma triquetra)*, spotted turtle *(Clemmys guttata)*, eastern fox snake *(elaphe vulpina gloydi)*, channel darter *(Percina copelandi)*, and river darter *(Percina shumardi)*. Listed plant species include three-awned grass *(Aristida longespica)*, sedge *(Carex seorsa)*, beak grass *(Diarrhena americana)*, showy orchis *(Galearis spectabilis)*, whorled pagonia *(Isotria verticillata)*, and hairy mountain-mint *(Pycnanthemum pilosum)* (MNFI, 1999). There are also 14 animal species and 8 plant species that have been listed as species of special concern by MDNR (MNFI, 1999).

3.2 AFFECTED MEDIA

This section provides a preliminary assessment of media in the Tittabawassee River and floodplain, based on pooled data from studies conducted to date by Dow, its contractors, and MDEQ, as described in Section 2.2.

3.2.1 Distribution of Chlorinated Furans and Dioxins

Data used to perform a preliminary evaluation of the nature and extent of furans and dioxins in Tittabawassee River sediment and floodplain soil were obtained from previous investigations and the Scoping Study (CH2M Hill, 2005c). Sediment and floodplain soil data were compiled into a database and analyzed using a Geographic Information System (GIS) and other tools. Furan and dioxin data in this section are presented as World Health Organization Toxicity Equivalency Quotient concentrations (WHO/TEQ). This means that World Health Organization mammalian "toxic equivalency factors" (WHO/TEF) were applied in deriving estimates of TEQ, using the measured concentration of each furan and dioxin congener and then multiplying by the corresponding WHO/TEF. The individual TEQ products are summed to determine the sample Total TEQ concentration (expressed in 2,3,7,8-tetrachloro-dibenzo-p-dioxin (TCDD) "equivalents") using the following equation:

Total TEQ (2,3,7,8-TCDD equivalents) = Σ (Congener-specific concentration * Congener-specific TEF)

It is important to note, that previous investigations and related documents have incorporated furan and dioxin data derived from earlier WHO/TEFs (e.g., WHO 1998) however for this RIWP and all subsequent work products these data have been updated based upon the 2005 WHO/TEFs. For the *GeoMorph®* UTR site characterization the project QAPP specifies that in addition to reporting furan and dioxin TEQ values in samples, the actual <u>concentrations</u> of individual congeners are to be reported as well since the environmental fate and transport of these compounds will be related to the concentration and not necessarily to the toxicity-related TEQ calculated values.

3.2.1.1 Sediment

The sediment data available from studies conducted by MDEQ and Dow indicate that sediment TEQ concentrations are spatially variable, both horizontally and vertically. The median TEQ concentration in surface sediment over the length of the study area is 32 ppt; however, concentrations range from 0.58 ppt to 9,300 ppt. Previous investigations have reported that TEQ concentrations show no discernable pattern or trend with increasing distance from the Midland Plant.

Previous studies (CH2M Hill) have suggested that higher TEQ concentrations tend to be found in surface sediment (0 to 0.3 ft), as compared with deeper subsurface sediment (greater than 0.3 ft). However, these previous studies have indicated that concentrations (greater than 1,000 ppt) exist at depth (that is, greater than 0.3 ft), and no clear pattern or trend in TEQ concentration with depth is apparent. Previous investigations report that a high degree of vertical variability is generally found throughout the length of the Study Area and within individual cores. The 2006 *GeoMorph®* studies have reached different conclusions, which will be presented in the February 1, 2007 Site Characterization Report.

The analytical data from the 2006 sediment profiles collected from locations between the confluence of the Chippewa and Tittabawassee Rivers to just upstream of the Dow Dam indicates that the sediment upstream of the Dow bridges does not contain dioxins and furans at levels above background, however appreciable concentrations of these substances have been measured in levees and other depositional areas downstream. All 2006 analytical data will be provided in the February 2007 report for the *GeoMorph®* investigation of the upper six miles of the Tittabawassee River.

3.2.1.2 Floodplain Soils

Studies prior to 2006 reported median TEQ concentration in relevant surface floodplain soil data at 240 ppt, which is approximately an order of magnitude higher than the median concentration in Tittabawassee River sediment. Previous investigations also reported that TEQ concentrations appear to be less variable on a local scale than is the case for river sediments. In general, zones of higher and lower TEQ levels can be identified, and in some cases appear to show a trend of decreasing concentrations with distance from the river. No clear trends in floodplain soil furan and dioxin concentrations were found with increasing distance from the Midland Plant in studies prior to 2006.

As part of the evaluation of Scoping Study data, CH2M Hill performed statistical evaluations with the intent to assess potential relationships between surface floodplain soil TEQ concentrations and potential factors influencing the TEQ distribution. Their analysis showed that distribution of TEQ concentrations in the floodplain were most strongly predicted by two factors:

1) estimated distance from the river channel along flow paths predicted for an 8-year flood event (referred to as “streamline distance”), and

2) location of samples inside or outside of the 8-year Floodplain.

Both of these factors are strongly related to the processes that govern exchange of floodwaters and transport of solids between the river and floodplain. Streamline distance serves as a simplified surrogate for the complex suite of processes that govern erosion, transport, and deposition of solids in the floodplain, creating features such as natural levees and splays. The floodplain extent provides a natural limit to the area over which such transport can occur. For both of the factors described above, an 8-year flood event appeared to be a reasonable surrogate for the majority of the flooding events expected on the Tittabawassee River.

Other factors that were determined to have an influence on the predicted TEQ concentration in surface floodplain soil include TOC, grain size, and residence in a disturbed (cultivated) or undisturbed (forested) area. However, these factors were not found to be strong predictors when considered independently. The limited preliminary data available suggests that the vertical extent of furans and dioxins in floodplain soil decreases with increasing distance from the river channel. The observed trend is related to differences in accretion rate and other transport processes that may be occurring in the floodplain.

Solids deposited in the floodplain during the March 2006 flood event were collected at 48 locations along 8 floodplain transects and analyzed for dioxins and furans, as discussed in greater detail in Attachment E.

The thickness of sediment deposited during the event was also measured at each of these locations. Flood-deposited solids samples were collected on 20 inch squares of synthetic carpet, which were secured to the ground with metal stakes. Deposition was measured using 2-foot-square clay pads consisting of feldspar. Four samples were collected from each pad, centered in equal-sized quadrants, using a ¾ inch diameter stainless steel sampler with an opening allowing visual observation of the core along its length. Deposition was measured from the surface of any flood-deposited solids layer to the top of the feldspar horizon.

Total chlorinated dioxin and furan concentrations on [depositional] samples obtained from turf mats ranged from 25 ppt (TEQ), at an upland location near Saginaw Road at Caldwell Boat Launch, to 5,120 ppt (TEQ), at a near-bank high terrace location near Freeland Festival Park. The thickness of measured deposition was highly variable, even among quadrants of individual clay pads, and ranged from no erosion at multiple locations, erosion of the clay at some locations, to 70 mm of deposition at an intermediate terrace near the river bank in Imerman Park.

These deposition and erosion relationships are being further evaluated as part of the ongoing *GeoMorph®* SAP in the Upper Tittabawassee River. A preliminary analysis of the data from the natural (i.e., not bermed or sheet piled) overbank areas of the Tittabawassee River floodplain downstream of the Gordonville Road bridge, indicates that the following depositional patterns exist in the distribution of dioxins and furans horizontally and vertically within the geomorphic features and soil profiles:

3.2.1.2.1 Horizontal Deposition

- The geomorphic surfaces have different depositional patterns. The depositional pattern is directly related to their age and their proximity to the river.
- The overbank on the inside of meander bends has greater deposition than the overbank on the outside of the meander bend. The straight reaches of the river have similar deposition on both sides of the river except immediately downstream of a meander bend where the depositional pattern mimics the pattern in the meander bend.
- The horizontal extent of contamination includes the area within the upland scarp [in the floodplain] on both sides of the river.

3.2.1.2.2 *Vertical Deposition*

- The geomorphic surfaces immediately adjacent to the river that have received the majority of sediment deposition in the last 100 years typically have a contaminant pattern from the bottom of the profile to the top (ground surface) that typically is clean at depth, overlain by low levels of contamination, followed by high levels of contamination in the middle of the profile and lower levels of contamination at the surface. This is a common contamination pattern in river deposits where the contaminant source was active for a specific time period but has been eliminated as a source to the river in the recent past.

- The geomorphic surfaces further away from the river have a depositional pattern consisting of the contaminants located in the surface horizon and decreasing with depth. These areas have been stable from before the time of manufacturing and the contaminants have been deposited on top of the surface.

- The majority of the furans and dioxins are found in the natural levees adjacent to the river.

- The wetland and low terrace areas, approximately 300 feet from the river, have contaminants present from approximately 1 to 4 feet below ground surface.

- Furans and dioxins are found in the upper high terrace surface horizon to a depth of 1 foot or less in undisturbed areas.

- The vertical extent of contamination adjacent to the river is greater in the overbank on inside of meander bends than on the outside overbank of the meander bend.

3.2.1.3 Surface Water

Limited surface water sample data are available for furans and dioxins in the Tittabawassee River. Floodwater samples were collected from three locations in the river between March 31 and April 7, 2005, to initially characterize total suspended solids and furan/dioxin concentrations (CH2M Hill, 2005e). These preliminary samples indicated a range of TEQ concentrations between 0.002 and 0.01 ppt, reported as TEQ per total mass of sample, including both water and solids. Dissolved-phase concentrations were not measured and are expected to be very low due to the hydrophobic nature of these compounds.

Additional surface water samples were collected during both the March 10-20, 2006 and May 5-19, 2006 flood events, as described in greater detail in Attachment E. In-river samples were taken at two bridges (at Currie Parkway and Center Road), representing Tittabawassee River locations upstream of Dow's Midland facility and near the downstream confluence with the Shiawassee River, respectively. For each bridge location and time, samples were taken using a depth-integrated sampling device at three horizontal locations along the bridge transect delineating equal discharge increments, and were then composited into a single representative sample.

Overland flow surface water samples [from the floodway] were also collected during the March 2006 flood event at three floodplain locations (Study Area 1, Imerman Park, and the Shiawassee National Wildlife Refuge). Multiple samplers were placed at each location. Samples were collected by peristaltic pumps, which were activated by floodplain water level sensors.

In-river and overland flow samples were analyzed for total (dissolved and particulate) chlorinated furans and dioxins, and for total solids content. Total chlorinated furan and dioxin concentrations were then computed per unit of sample solids on a dry weight basis, as ng/kg or ppt. In-river samples at Currie Parkway ranged from 0.6 to 1.7 ppt (TEQ) during the March 2006 event and 0.2 to 0.3 ppt (TEQ) during the May event. In-river samples at Center Road ranged from 17.1 to 35.3 ppt (TEQ) during the March event and from 7.5 to 27.9 ppt (TEQ) during the May event. Overland flow samples [from the floodway] collected during the March event ranged from 14.7 to 39.6 ppt (TEQ) at Study Area 1, 2.9 to 194.8 ppt (TEQ) at Imerman Park, and 16.7 to 428.5 ppt (TEQ) at Shiawassee National Wildlife Refuge.

3.2.1.4 Groundwater

The potential presence of furans and dioxins in floodplain groundwater was investigated by MDEQ and the Saginaw County Health Department in 2003. MDEQ collected groundwater samples from 22 private water wells located adjacent to the FEMA estimated 100-year Floodplain as part of their Phase II Tittabawassee River/Saginaw River Dioxin Floodplain Sampling Study (MDEQ, 2003a). TEQ concentrations in the residential water well samples were confirmed to be less than the Maximum Contaminant Level of 0.03 ppt, which would be expected given the hydrophobic nature of furans and dioxins and the adsorptive capacities of soils.

3.2.2 Other Contaminants

As part of the Baseline Chemical Characterization of Saginaw Bay Watershed Sediments (MDEQ, 2002a), MDEQ analyzed a limited number of soil and sediment samples for a wide range of chemicals, including volatile organic compounds (VOC), semivolatile organic compounds (SVOC), pesticides and polychlorinated biphenyls (PCB), metals, and furans and dioxins. The findings from this study for chemical classes other than furans and dioxins were:

- VOCs: Except for one VOC positive (tetrachloroethylene) in a single sediment sample, VOCs were not found. MDEQ concluded that the lack of detectable VOCs was expected because of the flow regime of the Tittabawassee River.

- SVOCs: The SVOCs MDEQ found in soils and sediments were principally polynuclear aromatic hydrocarbons (PAH). MDEQ characterized the concentrations of PAHs in sediment and floodplain soil samples as relatively low. Hexachlorobenzene was detected in one sediment sample in this study.

- Pesticides and PCBs: MDEQ did not detect PCBs in sediment or floodplain soil samples. They did, however, find the pesticide DDT present in some sediment and floodplain soil samples. MDEQ noted that there had been a historical source of DDT on the Pine River (the former Michigan Chemical Company facility upstream of the Dow Midland facility), and the DDT may have originated from that source.

- Metals: Most metals occur naturally in sediments and floodplain soils. MDEQ concluded that the levels of metals measured were generally consistent with background levels. Two floodplain sample locations were an exception to this, with some metals concentrations (arsenic, chromium, copper, lead, mercury, nickel, and zinc) elevated sufficiently to pose a potential for minor aquatic impacts. MDEQ also noted that these two locations were downstream of a former plate glass manufacturing facility known to have discharged metal-bearing wastewaters to the Tittabawassee River.

The Phase II Tittabawassee/Saginaw River Dioxin Floodplain Sampling Study conducted by MDEQ focused on furans and dioxins in sediments and soils (MDEQ, 2003a). This study indicated that certain <u>furan</u> congeners predominate in the furan-dioxin congener mixture of samples collected within the FEMA estimated 100-year Floodplain downstream of Midland, whereas <u>dioxins</u> predominate in the congener mixture upstream of Midland and outside of the estimated 100-year Floodplain. Along with furans and dioxins, coplanar PCBs were detected in floodplain soil samples, and less frequently in sediment samples. Although some coplanar PCBs were found in soils and sediments, MDEQ has concluded that coplanar PCBs contribute very little to "dioxin-like" activity from these soils and sediments (MDEQ, 2003a).

The 2006 UTR *GeoMorph*® site characterization incorporates an expanded list of target analytes to determine the extent of contaminants other than furans and dioxins in sediments and soil. Samples from selected deposition zones will be analyzed for USEPA Appendix IX constituents, plus other secondary

COI substances selected collaboratively with MDEQ through the PCOI/COI/TAL process (see Section 5.1.1). Data from this effort will be reported in the UTR Site Characterization Report submitted in February 2007.

3.3 HISTORICAL PLANT OPERATIONS AND WASTE MANAGEMENT PRACTICES

The Midland Plant began operations in 1897 as The Dow Chemical Company. Expansion in production operations during the past century resulted in growth of the Midland Plant from 25 to approximately 1,900 acres. The majority of the Midland Plant is located on the east side of the Tittabawassee River and south of the City of Midland. Some of the current waste management (tertiary treatment ponds) operations are located on the southwest side of the river. The plant location and layout are depicted in Figure 3-3. The following subsections summarize the historical operations and waste management practices of the Midland Plant. Tables 3.3 and 3.4 at the end of this Section present listings of chemicals produced during the various stages of Midland Plant operations.

A Timeline summarizing historical operations at the Midland Plant, chemicals produced, waste management practices, and the development of environmental laws and regulations over time was developed during the preparation of this RIWP and is provided in Attachment F.

3.3.1 Overview of Plant Manufacturing Operations

Initially, the Midland Plant operations involved extracting brine from groundwater pumped from production wells ranging in depth from 1,300 to 5,000 feet below ground surface. Over the time of its operation, the Midland Plant has produced over 1,000 different inorganic and organic chemicals. These chemicals include the manufacture of 24 chlorophenolic compounds since the 1930s (Agin et al., 1984).

3.3.1.1 Early History of Dow Chemical

In the 1800s, bromine was an important chemical used in patent medicines, as a disinfectant, and in early photographic films. In 1878, the first successful brinewell was drilled in Midland, with Midland becoming a "center for bromine production [with] no fewer than 14 producers" over the next decade. Slab wood from lumber mills was used as cheap fuel to evaporate local brines to produce salt. "Bitterns" from the salt evaporators were "chemically oxidized to release the bromine." In 1890, Herbert Henry Dow, along with partner John H. Osborne, formed the Midland Chemical Company to extract bromine from cold brine using a novel electrolytic bromine recovery system. Early products included iron bromide, potassium bromide, and bromine purifier (Brandt, 1997; Dow, 1938; Dow, 1926; Leddy, 1989; Levenstein, 1998; Haynes, 1954a).

In 1893, an early experimental attempt to construct and operate a chlorine cell in Midland resulted in an explosion due to a build-up and mixing of hydrogen and chlorine gases. The Midland Chemical Company decided against further expansion in chlorine, and H.H. Dow left the company, moving to Navarre, Ohio, to continue his experiments with electrolytic chlorine cells. He joined with James Pardee and several other backers to form the Dow Process Company in Navarre. By 1896, Dow had completed development on the chlorine cell and had established a manufacturing process for the production of bleach or “chloride of lime” (calcium hypochlorite). He closed the Ohio plant and returned to Midland, Michigan. He built a small electrolytic chlorine cell room and bleaching powder plant, leasing land from the Midland Chemical Company and purchasing their debrominated brine for the process. This original bleach plant was made of tar, wood, iron, glass, and concrete (Brandt, 1997; Dow, 1926; Haynes, 1954a; Karpiuk, 1984).

By 1897, the “new” Dow Process Company in Midland had been reorganized as The Dow Chemical Company and began the manufacture of bleaching powder using waste brine from bromine production operations. The chlorine plant consisted of nine electrolytic chlorine production cells using arc-light carbon rod cathodes in tarred wood houses (40 feet wide by 368 feet long) and a slaked lime absorber (also, 40 feet wide by 368 feet long). Dow inserted wooden troughs around each bank of carbon rods to “trap” the chlorine. This was the basis for calling these early cells, the “trap cells”. The alkalinity around the cathodic portions of the carbon rods caused a gelatinous precipitate of the hydroxides of iron, magnesium, and calcium to form on the surface of the carbon, which acted as a diaphragm to prevent the hydrogen and chlorine from mixing and exploding. (This gelatinous mass filled the cells within a week and required a shut-down for cleaning.) Chlorine was conducted from the cells in wooden pipes made of bored-out pine logs, cooled with water, and then passed over scrap zinc to dry it sufficiently to make good bleaching powder by reaction with lime. The cells did not make caustic soda at that time. Eventually there were 16 cell buildings with 2 million carbon rods in service in 26,000 traps (Haynes, 1954a; Karpiuk, 1984; Leddy, 1989).

The first commercial sales of bleaching powder began in 1898. Production increased from 9 tons of bleaching powder per day in 1897 to 72 tons per day in 1902 (20,000 tons/year) (Haynes, 1954a).

In 1899, the carbon electrodes (“carbons”) of the new chlorine cells were treated by soaking in molten paraffin (135°F melting point) to plug pores for the purpose of preventing explosions. Historical anecdotal information indicates that the tarred pine boards holding the carbon electrodes became “spongy” with exposure to the “corrosive chemicals” in the cells, and that replacing them “during the down-time” improved cell efficiency (Karpiuk, 1984).

During this early time period, Dow Chemical also began production of sulfur chloride, various bromides, mining salts, Epsom salts, and magnesium carbonate, maximizing the economic return from the rich mineral resources available in the brine (Levenstein, 1998).

In 1902, the Midland Chemical Company merged into The Dow Chemical Company. That same year, H.H. Dow organized a new Midland Chemical Company, differentiated from the original by being called Midland Chemical Company II, for the commercial synthesis of chloroform from carbon tetrachloride, using sulfur chloride from Dow’s chlorine cell operation. Chloroform and carbon tetrachloride were first commercially available in 1903. The production building, known as 3-B and located on land leased from The Dow Chemical Company, continued to produce chloroform until 1942. Midland Chemical Company II was combined with The Dow Chemical Company in 1914 (Brandt, 1997; Dow, 1939; Haynes, 1954a; Karpiuk, 1984).

Between 1904 and 1905, Dow began the manufacture of benzoic acid by treating toluene with chlorine and then converting the resultant benzyl chloride into benzoic acid. This represented Dow’s first venture into benzene ring chemistry (Haynes, 1954a).

By 1908, Dow manufactured two principal products, bromides and bleaching powder, and other small-volume products based on bromine and chlorine extraction, including mining salts, chemical insecticides and food preservatives, sulfur chloride, benzyl chloride and benzoic acid, carbon tetrachloride, and chloroform. In 1908, H.H. Dow formed the Midland Manufacturing Company in equal partnership with the Fostoria Glass Company and the Libbey Glass Company to develop an electrolytic caustic potash cell to make chlorine and potassium hydroxide. This process produced minor amounts of potash. In 1910 Dow Chemical had its first sales of lime sulfur (calcium sulfide) and lead arsenate sprays. In 1911, both glass companies dropped out of the Midland Manufacturing Company (Brandt, 1997; Campbell and Hatton, 1951; Haynes, 1954a; Karpiuk, 1984; Levenstein, 1998).

In 1911, Dow scientists improved brine processing by developing a more sophisticated and efficient cell design. In the new plant, after removal of the bromine, the brine flowed into a vacuum evaporator, where steam heat and low pressure efficiently and rapidly boiled the brine and removed water. With evaporation, sodium chloride first precipitated and was removed. The liquid then passed into a second evaporator where magnesium chloride precipitated from the solution. The remaining viscous liquid was then transferred to a third evaporator, which removed the rest of the water, producing solid calcium chloride. In the spirit of economical extraction of benefits from the brine, Dow again increased the number of viable products obtained from the brine. Prior to this process improvement, only bromine and chlorine were recovered; the rest of the components of the brine were handled as waste materials (Haynes, 1954a; Karpiuk, 1984).

In 1913, Dow scientists further refined the chlorine-caustic soda electrolytic cell. These cells produced two usable products at the same time: chlorine and caustic soda. They used the salt from the first stage vacuum evaporator and re-dissolved it in water as a feedstock. New vertical-filter-press cells were constructed of concrete and graphite rather than wooden frames and arc-light carbons. Dow "had elected to use 75 cells in a filter press series." Dow's new "bipolar cells" (steel as the cathode and graphite as the anode) achieved "electrical continuity…internally, with external connections to the rectifier circuit being made only at the anode and cathode terminals of a series which contains a multiplicity of cells" (Karpiuk, 1984).

In 1914, H.H. Dow abandoned his original "trap cells" in favor of the newer "bipolar cells," and announced the company would quit the manufacture of bleaching powder. He told associates the "real future of the Company lay in the use of its chlorine for products other than bleaching powder, especially chlorinated hydrocarbons." Dow produced its last bleach in July 1915. Demand was shifting from bleaching powder to chlorine, prompted by chlorine's effectiveness in stemming typhoid outbreaks by direct injection into domestic water supplies; the blockade of German dyestuffs and organic intermediates; the liquefaction of chlorine and its transport in cylinders and tank cars; and the introduction of liquid chlorine into the manufacture of pulp and paper after World War I (Haynes, 1945a; Haynes, 1945b; Haynes, 1949; Leddy, 1989; Karpiuk, 1984).

3.3.1.2 Manufacturing After Bleach

During World War I (1914-1918), in response to the British Navy's blockade of German exports and subsequent increased domestic demand, Dow began the manufacture of phenol using a benzene-sulfonation process. Dow manufactured 40 tons per day for use in producing trinitrophenol for artillery shells. Dow's dramatic increase in phenol production was in response to the United States increase in demand. (Whitehead, 1968) Other wartime-introduced products included dichloroethylsulfide (for mustard agent), monochlorobenzene (for explosives), and hexachloroethane (for smoke screens). In 1918, the United States Army operated a plant manufacturing mustard agent based on chlorine at the

Midland Plant. The United States manufactured up to 10,000 pounds per day of mustard agent (Brandt, 1997).

During this same period Dow also began to produce acetic anhydride, ethylene glycol, ethylene chlorohydrin and its acetate, dichloroacetic acid, aspirin and other salicylates, calcium chloride, dichloroethylsulfide, monochlorobenzene, hexachloroethane, sodium acetate, trichloroethylene, trinitrophenol, and tetrachloroethylene. Also in response to wartime demand, Dow began commercial production of synthetic brominated indigo (400 pounds/day by 1917) and its intermediates, aniline and chloroacetic acid. Military needs for incendiary flares prompted the production of magnesium metal (3000 pounds/day by 1917), produced by electrolysis of magnesium chloride. Dow continued production of inorganic bromide- and chloride-based products, including caustic soda (50 tons/day by 1916), chlorine (45 tons/day by 1916), bromine, Epsom salts, magnesium products, and insecticides (Bennett, 1926; Brandt, 1997; Dow, 1939; Haynes, 1945a; Haynes, 1945b; Leddy, 1989).

In 1918, Dow perfected a new synthetic process for production of phenol using chlorobenzene. This process used high pressure in a continuous system and yielded *o*- and *p*-xenols (phenylphenols). Shortly thereafter, Dow began production and marketing of Paradow™ (p-dichlorobenzene) (Haynes, 1945a; Haynes, 1945b).

Beginning in 1919, Dow began promoting its new magnesium alloy, Dowmetal™, for structural uses. By 1927, Dow was the sole domestic producer of magnesium and by 1929 was producing over 840,000 pounds annually. By 1942, Dow was producing 91 percent of all magnesium produced in the United States. During the years immediately before and during World War II (1939-1945), Dowmetal™ became one of Dow's largest products by tonnage measure (Dow, 1939; Haynes, 1945a; Haynes, 1945b).

Table 3.3 provides a list of products manufactured at Dow Chemical circa 1926-1928. During the 1920s Dow resumed production of its peacetime products and introduced several new products, including synthetic amino acids, phenylethyl alcohol, vinyl chloride, carbonic acid, ethylene dibromide, ethylene dichloride, propylene dichloride, synthetic oil of wintergreen (methyl salicylate), coumarin, synthetic ammonia, trichloroethane, and trichloroacetic acid. A larger plant was built in 1921 for production of acetylsalicylic acid (aspirin). By 1927, annual commercial production of phenol manufacture exceeded 8 million pounds, owing to an improved heat exchange system developed by Dow chemists W.H. Hale and E.C. Britton. In 1929, a new method for preparation of aniline from chlorobenzene and aqua ammonia led to the development of Dowtherm™ heat transfer fluids (at that time, a mixture of diphenyl and diphenyloxide) (Dow, 1939; Haynes, 1945a; Haynes, 1945b; Dow, 1928; Midland Sun, 1926).

During the early 1930s, Dow began marketing a hydrochloric acid treatment method to revive old wells (Dowell™), and developed ethyl cellulose, Dow's first plastic, which was used extensively during World War II for telephone headsets, dust goggles, airplane parts, etc. During this time, Dow also began production of vinylidene chloride and 1,1,1-trichloroethane. In the mid-1930s, the Midland Plant began producing various chlorinated phenols, both directly for sale and for use as intermediates in the production of other chemicals. These chemicals were used primarily as fungicides, bactericides, or herbicides (Dowicides™). Dow scientists also invented the Dow styrene monomer process during this time, which consisted of passing ethylbenzene vapors through superheated steam to bring about partial dehydrogenation of ethylbenzene using special low inventory stills. Commercial production of polystyrene (Styron™) followed in 1938. Also during this time period, the Thiokol Company arranged for Dow to begin production of Thiokol synthetic rubber at the Midland Plant and, by 1938, Dow had moved into large-scale production, producing over 2 million pounds annually. By 1939, Dow was producing 100 tons of Epsom salts per day and over 41 million pounds of aniline per year. By this time, Dow scientists had also worked out the polymerization and fabrication techniques for a copolymer of vinyl chloride and vinylidene chloride (Saran™). During this period, Dow experienced steady growth, becoming the single largest domestic producer of chlorine, the majority of which was used in the manufacture of various Dow products (Agin et al., 1984; Brandt, 1997; Dow, 1928; Dow, 2006; Haynes, 1948; Karpiuk, 1984; Whitehead, 1968).

As Dow entered the 1940s, over 500 products were being manufactured at the Midland Plant, which by then covered 525 acres. Dow added 2,4-D herbicide to its product line and built a larger production facility. Dowex™ ion exchange resins were developed and used for purification of water, liquid food, and other materials. In an attempt to make a flexible, low loss dielectric for early radar applications, Dow scientists tried to copolymerize styrene with isobutylene. Rather than copolymerizing, the isobutylene vaporized within the styrene polymer, forming a rigid cellular product that paved the way for Styrofoam™.

During World War II, additional plant facilities were made available for Thiokol production. Several new products were introduced, many in response to wartime needs. In addition, Dow operated the Midland Chemical Warfare Service (CWS) Plant for the production of CC-2 from February 1943 to April 1944 (Brandt, 1997). CC-2, also known as impregnite, was used during World War II for the impregnation of clothing for protection against vesicant agents such as mustard agent and lewisite. The plant plans were based on a DuPont pilot plant. By April 1944, the military forces had sufficient stockpiles of impregnite and the plant was placed on standby. It never operated again (Brandt, 1997).

In 1947, a new pentachlorophenol plant was built. By the end of the decade, over half the American domestic production of phenol was produced at the Midland Plant (Brandt, 1997; Haynes, 1954b). See Table 3-4 for a listing of new products introduced during the 1940s.

During the 1950s the Midland Plant expanded its manufacturing capacity of existing products and added several new products including acrylic acid, acrylamide, ethanolamines, phenolics, herbicides, soil fumigants, polyacrylamide and other plastics, and styrene/butadiene latexes. By the end of the 1950s, chemicals accounted for 53 percent and plastics accounted for 35 percent of Dow sales (Brandt, 1997; Dow, 1947; Karpiuk, 1984). See Table 3-4 for a listing of new products introduced during the 1950s.

In the 1960s, the Midland Plant continued to expand both its production capacity and the number and range of products being manufactured, while ceasing to produce other products. Many of the new products introduced during the 1960s would be produced through the mid-1970s, with a few of these products continuing in production into the 1980s and beyond. In 1964, Dow improved the 2,4,5-T production process to increase efficiency and reduce waste. During the late 1960s, Dow built a new trichlorophenol plant and a new chlor-alkali plant and expanded existing plant operations for ethylbenzene, styrene, bromine, bisphenol A, and polystyrene (Dow, 1960; Dow, 1966; Dow, 1970). Table 3-4 provides a listing of products introduced during the 1960s.

In the 1970s, Dow commenced full-scale production of the chlorpyrifos insecticides Dursban™ (household market) and Lorsban™ (agricultural market). Dow also introduced 2-chloro-*N*-isopropylacetanilide (Propachlor™). During the early to mid-1970s, the chlorine/caustic facilities were modernized. Also, a new 2,4-D herbicide plant was built that provided recycling of much of the process water and by-products, and the existing chlorinated benzene production facilities were replaced and expanded to more efficiently produce monochlorobenzene, *o*- and *p*-dichlorobenzene, trichlorobenzene, and tetrachlorobenzene. During the mid- to late 1970s, Midland stopped production of 1,2-dibromo-3-chloropropane (Fumazone™), *o*,*o*-dimethyl-*o*-(2,4,5-trichlorophenyl) phosphorothioate (Ronnel™), and 2,4,5-T (Dow, 1966; Dow, 1970).

In the 1980s and 1990s, on-site production began to decrease both in terms of capacity and range of products. The Midland Plant pentachlorophenol manufacturing facility was closed in October 1980. Also during this time, the decision was made to shut down the chlorine/caustic soda production facilities and, by the mid-1980s, the Midland Plant exited the brine business. At this time, Dow doubled its household product lines producing Saran Wrap™, Handi-Wrap™ and Scrubbing Bubbles cleaner. Dow also introduced Seldane™, a non-sedating antihistamine, and Drytech™, the active absorbent in disposable diapers. In 1998, Dow exited the magnesium business (Brandt, 1997; Dow, 1973; Dow, 1975; Dow, 1977; Dow, 2006a; Amendola, 1986).

Currently, the Midland Plant consists of approximately 30 production plants and a core centralized Research & Development campus that serves Dow's global operations. The Midland Plant has been and remains a major research and development center for Dow. The research and development conducted at present is a mixture of pure research up to and including the construction of pilot plants to test manufacturing processes prior to construction of manufacturing facilities at Dow's various global locations.

3.3.2 Overview of Plant Waste Management Practices

Waste management practices have evolved with the changing production and regulatory environment. Waste management practices at the Midland Plant have included on-site and off-site treatment and disposal of various waste products (MDEQ, 2003b). In the very early history of the Midland Plant, wastes were discharged directly to the Tittabawassee River and, sometime later, wastes were stored and treated in ponds. Other wastes were disposed of on-site either on land or by burning (Agin et al., 1984). Over time, improvements in waste management practices included the installation and operation of a modern wastewater treatment plant as well as the use of incinerators instead of open burning. Improvements in the wastewater treatment plant and subsequent incorporation of pollution controls into both the operations of and emissions from the incinerators have reduced or eliminated releases and emissions from the Midland Plant.

Historic waste burning and waste incineration appear to be the primary source of elevated furans and dioxins found in surface soil in the Midland Study Area, as reported in "Point Sources and Environmental Levels of 2,3,7,8-TCDD (2,3,7,8–tetrachlorodibenzo-*p*-dioxin) on the Midland Plant Site of The Dow Chemical Company of Midland, Michigan," (November 5, 1984) ("1984 Report") (Agin et al., 1984). This study conducted by Dow was "a comprehensive search for all critical point sources of 2,3,7,8-TCDD to the air, soil, and water in the Midland area." The results of the study were submitted to federal, state, and local governmental agencies. The 1984 Agin Study contains details about historic manufacturing processes and waste management practices, focusing on 2,3,7,8-TCDD. The study predated the discovery of significant concentrations of furans and dioxins in and along the Tittabawassee River although the federal and state governments were aware of 2,3,7,8-TCDD in fish, through their own studies and Dow studies, in the Tittabawassee and Saginaw Rivers.

Elevated furan levels in and along the Tittabawassee River appear to be primarily attributable to early brine electrolysis for chlorine manufacturing, and associated waste management practices of the period at the Midland Plant. Prior to the construction of wastewater storage ponds in the 1920s, wastes from manufacturing processes were discharged directly to the Tittabawassee River.

3.3.2.1 Historical Aqueous Waste Management

Beginning in the 1920s, aqueous waste was managed using a network of collection ditches, pipelines, and pumps that delivered waste to a series of storage ponds. Outlet structures controlled releases to the Tittabawassee River during high river flow periods. Approximately 30,472 barrels per day of waste brines were placed in a series of storage ponds. Two additional ponds were constructed during the 1930s, resulting in over two years of waste brine storage capacity at then present waste brine pumping rates. Sludges were stored in a 64-acre pond designed to collect and thicken suspended matter. Organic system wastes, defined by odor, were also stored in ponds designed for long retention periods. Acid wastes were stored in a 109-acre pond system during cold months; during warmer months discharges to the River were controlled based on temperature and stream condition. Clear water wastes from condenser and cooling waters were continuously discharged. Discharges were periodically monitored for sodium chloride concentration and phenol content (Michigan Stream Control Commission, 1937). Leaching from waste impoundments located near the river impacted the groundwater, which may have subsequently discharged to the river.

In the 1930s, a secondary wastewater treatment plant (trickling filter) was built and operated to treat phenolic wastes. As Dow increased production to meet the government's demands, Dow's efforts to upgrade its treatment plant were delayed due to denials of materials by the United States War Production Board (Bay City Times, 1947). However, in 1945, the wastewater treatment plant (WWTP) was upgraded to include preliminary treatment in trickling filters followed by activated sludge treatment and final clarification (Velz, 1958). The wastewater treatment processes have undergone several upgrades over the years, including the construction of tertiary treatment ponds (referred to as "T-ponds") in 1974. In 1985, mixed media sand filters were constructed to remove particulates from the tertiary effluent prior to discharge to the river. Operation of the T-ponds has been regulated by Dow's NPDES permit since 1988. Historically, the WWTP received flows from the process areas and sanitary wastewaters. During the 1970s and 1980s, additional flow contributions were directed to the WWTP, specifically waste scrubber water from the rotary kiln incinerator and tar burner, sludge dewatering system discharges, cooling tower blow down, other non-contact cooling water, water softener backwash, tank car washings, surface water runoff, and leachate from the Salzburg Landfill. At present, sanitary and laboratory sink wastes are directed to the Midland municipal waste treatment facility along with sanitary wastewaters from the MCV plant (MDEQ SQD, 1970-2000).

Effluent from the WWTP discharges to the Tittabawassee River via an outfall. Historically, up to 11 outfalls from the Midland Plant discharged to the Tittabawassee River (MDNR, 1972). Over time, the number of outfalls was reduced to a primary process wastewater outfall, with one emergency back up outfall and several storm water outfalls. (Refer to Section 3.1.5 of this document for more information on outfall history and locations.)

By 1984, through efforts to recover and reclaim process wastewaters, the wastewater effluent discharge flow to the River had dropped from 35.4 million gallons per day (MGD) to 20 MGD. Continued efforts throughout the 1980s and 1990s resulted in construction of several process waste recovery and reclamation facilities and subsequent reduction of influent pollutant loads at the facility-wide WWTP.

During the early 1980s, Dow discontinued the use of deep disposal wells for discharge of phenolic wastes. These wells discharged into the Sylvania formation and the Dundee formation. Historic deep well disposal activities are presently being investigated as part of the On-Site Corrective Action Program.

In the late 1970s, construction began on a 2.5 mile-long Revetment Groundwater Interceptor System (RGIS). The T-Pond RGIS system was added in 1992. The RGIS flanks most of the plant site on both sides of the river. From 1990 to the present, upgrades and replacement work have continued to take place on the RGIS. A new horizontal interceptor pipe system was constructed in 2002 along a portion of South Saginaw Road. The estimated length of all the perforated pipe horizontal interceptor systems total is approximately 7 miles (Agin et al., 1984).

3.3.2.2 Uncontrolled Aqueous Release Management

The Tittabawassee River has a long history of significant flood events, with records dating back to the late 1800s. During the early years of the Dow facility, flood control in the River was especially troublesome, many times resulting in inundation of the plant site and waste treatment facilities. Particularly severe storm events have caused flooding of the entire Midland region, including the Dow facility. These heavy floods usually occurred during the spring and resulted in discharges to the Tittabawassee River of stored brines and untreated or partially treated process wastewaters. The most common releases to the River as a result of flooding were overflows from the brine storage and tertiary treatment ponds (MDEQ SWQ files 1970-2000; MWRC, 1960; Midland Daily News, 1950).

As in any manufacturing operation of this size, accidental spills of process materials and infrequent excursions of isolated parameters above the WWTP NPDES discharge permit levels occurred at the Midland Plant. Beginning in the early 1970s, Dow recorded reportable spills and excursion events and reported them to the MDEQ, Surface Water Quality Division (SQD). While some of the reported spills resulted in releases to the Tittabawassee River, many were contained, controlled, and/or treated through the on-site WWTP and did not result in a direct release to the River. Reported NPDES excursions have been promptly addressed (MDEQ SWQ files, 1970-2000).

3.3.2.3 Historic Air Emissions Management

3.3.2.3.1 *Process Emissions*

Historically, waste process gases were vented to the atmosphere. Dow chemists and engineers have always viewed waste materials as process inefficiencies. As a result, efforts have been focused on recovering wastes for reclamation and reuse (Agin, et al., 1984; Haynes, 1945a; Haynes, 1945b; Haynes, 1948; Haynes, 1949; Haynes, 1954a: Haynes 1954b). Beginning in the late 1960s, Dow more aggressively pursued reduction in emissions from its process vents through process changes or elimination, implementation of material recovery and reuse, and installation of air pollution control technologies (Agin, et al., 1984; Dow, 2006a).

Due to the high demand for electrical power, Dow has historically supplied its own power needs using on-site power generation plants. As of 1984, the on-site 60 megawatt electrical, two million pound per hour steam cogeneration plant (Plant Powerhouse) burned 2000 tons of coal per day. Exhaust gases were directed through an economizer prior to stack exhaust to the atmosphere. The powerhouse was retrofitted with baghouse filters in October 1982 to remove 99 percent of the flyash previously discharged to the environment (Agin, et al., 1984). During 2006, an additional area of elevated 2,3,7,8-TCDD was identified adjacent to the butadiene tank farm. This area is presently being investigated as part of the on-site corrective action program.

3.3.2.3.2 *Airborne Deposition and Fugitive Dust Emissions*

Exhaust constituents from process vents, power generation, and thermal destruction processes may have deposited onto plant soils. During dry periods, desiccated Midland Plant soils may have resulted in fugitive dust emissions. Samples of Midland Plant soils at the plant fence line have shown higher levels of chlorinated dioxins than soils located in distant City of Midland residential soils. Current information indicates that concentrations in Midland Plant soils (average is less than 1 ppb) decrease radially from inside the plant outward, suggesting a windborne mechanism. The Midland Plant soils with the highest concentrations of dioxins were located near historic chlorophenolic production areas, the waste incinerator, and ash handling facilities (see discussion on combustion of solid wastes below.) Two small areas directly associated with the long-term manufacture or handling of chlorophenolic production compounds (477 Building and the area by 11th and J Street) demonstrated the highest levels of chlorinated dioxins. These areas occupy less than 0.5 percent of the total land surface of the Midland plant site. Concentrations in these areas were localized and dropped off dramatically within a few hundred feet, suggesting that fugitive dust transport was not a major occurrence in these areas (Agin, et al., 1984). During 2006, an additional area of elevated 2,3,7,8-TCDD was identified adjacent to the butadiene tank farm. This area is presently being investigated as part of the on-site corrective action program.

3.3.2.3.3 Early Combustion of Liquid Waste Tars

As early as 1930 the Dow Midland facility disposed of organic liquid tars by incineration. Two basic types of incineration were used: liquid tar burners using several different configurations and rotary kiln solid waste trash incineration. Improvements in burn efficiency and environmental controls have been consistently made since this time. In 2003, Dow completed upgrades to several of its thermal destruction devices to meet USEPA Maximum Achievable Control Technology (MACT) standards for industrial incineration devices (Agin, et al, 1984; Dow, 2006a).

In the mid 1930's two tar burners were installed northwest of the present Midland Plant waste incinerator. Liquid tars were burned inside vertical brick lined towers with combustion exhaust gases and particulates vented directly to the atmosphere. Fuel oil was also used to assist in start up and maintenance of the burner flame (Agin, et al., 1984).

In 1951, a new vertical tar burner replaced these two units. Within the new 15-foot diameter by 50-foot tall brick-lined tower, four tangential feed nozzles dispersed process wastes, blended with supplemental fuel oil, for incineration. Combustion exhaust gases and particulates were vented directly to the atmosphere. This unit was removed from service in 1974 and demolished in the late 1970s (Agin, et al., 1984).

In 1957, the 707 Building tar burner was constructed just east of the present Dow Midland plant waste incinerator. This unit provided air exhaust scrubbing equipment to reduce hydrogen chloride emissions when burning chlorinated tars. Depending on the materials undergoing incineration, the vent emissions could be diverted directly to a 125 foot stack or to a water quench chamber prior to venting to the atmosphere. This unit was removed from service in 1975 (Agin, et al., 1984).

High temperature (approximately 1,000 ^{o}C, or higher) combustion of organic liquid tars began in 1968 with construction of the 830 Building tar burner. This unit operated at a temperature of 900-1,000 ^{o}C with a tar feed rate of 10 gallons per minute (gpm). Combustion exhaust gases and particulates (30,000 cubic feet per minute (cfm)) were directed through a water quench system, venturi scrubber, and demister before stack discharge. In 1975, chlorinated waste tars were directed to the afterburner of the rotary kiln incinerator (discussed below). In 1981, this unit was placed in standby mode to be used only for tar inventory control. The unit has not operated since December 1982 (Agin, et al., 1984).

Three natural gas augmented incinerators for destruction of process halogenated by-product streams were in operation by 1984. The 1058 Building burner was designed to destroy waste chlorinated aromatic materials and recover usable hydrogen chloride. The 564 Building burner was designed to destroy waste chlorinated monomers. The 1009 Building burner was designed to burn a variety of halogenated waste solvents and by-products.

3.3.2.3.4 Combustion of Solid Wastes

Prior to 1948, solid wastes were either landfilled on the Midland Plant site or stockpiled for open air burning. In 1948, a rotary kiln incinerator was placed in service to burn rubbish, waste solids, packs, and liquid tars. Solids were manually shoveled into the feed chute and various liquids were sprayed into the front of the kiln. Combustion exhaust gases and particulates were vented directly to the atmosphere (Agin, et al., 1984).

In 1958, this original rotary kiln was replaced with a new dual rotary kiln system (703 Building Kiln No. 1 and Kiln No. 2) to burn paper and wood trash, solid chemical waste, chemically contaminated waste equipment, and a variety of liquid wastes. From 1958 to 1975, only Kiln No. 1 was used. This unit provided increased capacity and improved burner control. The operating temperatures in the rotary kiln ranged between 500-900^{o}C with a 30-45 minute bulk solid residence time. Combustion exhaust gases and particulates were directed through a water-spray quench system before discharge to the atmosphere. In 1970, to reduce stack particulate emissions, a secondary combustion unit afterburner (using natural gas for supplemental fuel) was installed between the kiln and the quench chamber. In 1975, the Kiln No. 2 was placed into service and Kiln No. 1 was shut down. The Kiln No. 2 system included a rotary kiln, an improved afterburner and air pollution control system consisting of a water quench system, venturi scrubber, and demister. Beginning in 1978, in response to research studies indicating that a higher temperature was needed to minimize formation of chlorinated dibenzo-p-dioxins and to assure their efficient destruction, natural gas was added to the afterburner to increase the temperature control point to approximately 1000°C. In 1981, the addition of a wet electrostatic precipitator to the Kiln No. 2 system resulted in further reduction of particulate emissions to the atmosphere. By 1984, further improvements, including process computer control, resulted in the afterburner operating temperatures between 1000-1100°C with a residence time of a few seconds. Liquid wastes and tars were atomized either directly into the kiln or directed to the afterburner, with higher BTU liquid feeds and dichlorophenol distillation wastes directed to the afterburner and higher ash-containing feed directed to the kiln. Mass flow measurements of 2,3,7,8-TCDD levels in the incinerator system in 1984 showed that the incinerator ash captured about one-half of the 2,3,7,8-TCDD. The other half was 95 percent captured by the exhaust scrubber equipment (Agin, et al., 1984).

Historically, wet kiln ash was lifted from the ash trough by conveyor belt to dump trucks for transport to on-site landfill disposal. From 1979 to 1982, after closure of the on-site landfills and before completion of the Salzburg Landfill, kiln ashes were stockpiled in an open area south of 11th Street and west of the waste incinerator. The pile was sprayed regularly with an aqueous dust suppressant to minimize desiccation and fugitive emissions of particulates. In 1982, a building was constructed around the ash transfer operation to totally enclose the conveyor and truck loading operation. Ash handling methods were also implemented to prevent drying and dusting of kiln ash at all stages of loading, transport, and landfilling (Agin, et al., 1984).

Prior to 1985, liquid waste being fed to the secondary combustion chamber burner was atomized through the use of an air fan. The type of burner nozzle was changed to employ the use of steam atomization, which was more efficient, thereby lowering the amount of 2,3,7,8-TCDD that was formed. To lessen the amount of particulates, several improvements were added to the 703 incinerator in the 1987-1988 time frame. The venturi scrubber was modified to employ a variable throat, which created a greater pressure drop. A series of high efficiency water nozzles were added to the entrance into the quench tower. This greatly improved the efficiency of the venturi scrubber (Dow, 2006b).

In 1988, the secondary combustion chamber of the 703 incinerator was reconfigured. A high efficiency vortex burner was installed just after the rotary kiln. This installation increased the secondary combustion zone residence time significantly and employed a highly efficient burner. These changes allowed Dow to demonstrate within the year that this burner was capable of 99.99 to 99.999 percent efficiencies (Dow, 2006b).

In 1990, another rotary kiln incinerator, 830, replaced the existing 830 tar burner. This unit had a sixty foot long rotary kiln with two 30 million BTU per hour (BTU/hr) burners, and a large secondary combustion chamber with over two seconds residence time. This chamber was fitted with two 30 million BTU/hr vortex burners. From the combustion chamber, gases flowed through the following units: a rapid quench chamber, an HCl absorber, a variable throat venturi scrubber, a demister, an initial fan, four ionizing wet scrubbers, a second fan, and then to the stack. This unit was permitted at 99.999 percent efficiency (Dow, 2006b).

Planning for the new, state-of-the-art 32 Building rotary kiln began in the late 1990s. This new kiln was built to insure that Dow could meet the forthcoming MACT standards. The kiln was designed to burn both solid and liquid wastes. The kiln, which had two 35 million BTU/hr burners, was outfitted with carbon seals on both ends to greatly minimize the possible occurrence of fugitive emissions. Where older kilns often had less than 0.25 inch of water vacuum on the combustion chamber, the new kiln was designed to run at greater than 1 inch of water vacuum (Dow, 2006b).

Exhaust gases from the new rotary kiln pass into a large circular secondary combustion chamber having a 3.5 second retention time where three 30 million BTU/hr burners fire tangentially into the chamber. After the secondary combustion chamber, the gasses pass into a NO_x reduction system then into a rapid quench designed to minimize dioxin formation. From the quench chamber, the flue gases pass into a packed condenser tower which removes most of the hydrochloric acid that is formed in the combustion process. The condenser tower also aids with the pre-treatment of particulates prior to entering the high energy venturi scrubber. After the venturi, which removes the bulk of particulates in the gas stream, the flue gases pass into a packed tower chlorine scrubber. Sodium hydroxide is used to react with any remaining residual chlorine in the gas stream. After the chlorine scrubber, the gases are pulled through the first induced draft fan. From the fan, the gases pass through nine ionizing wet scrubber (IWS) units, which remove the last of the fine particulates from the gas stream. From the IWS's, the gases pass through a second induced draft fan and then up a 200 foot stack. At the stack, oxygen, carbon monoxide, SO_x and NO_x are continuously monitored (Dow, 2006b).

After starting up the 32 Building kiln in 2003, the 703 Building and 830 Building incinerators were closed under RCRA requirements. Whereas the older units were permitted to process 85 million BTU/hr and 60 million BTU/hr, the new 32 Building kiln was licensed to operate at 130 million BTU/hr. This reduction in capacity was possible because Dow had implemented new technologies to recycle wastes as useful raw materials (Dow, 2006b).

By 2003, Dow had completed upgrades to its thermal destruction devices to meet USEPA MACT standard for industrial incineration devices. Between 2003 and 2006, Dow implemented new technology to further improve the performance of their thermal destruction devices. Since, 1995, Dow has reduced dioxin emissions to the air by over 95 percent (Dow, 2006a).

Table 3-3 Products Circa 1926-1928

The Dow Chemical Company

acetic acid	Dowmetal™	orthodichlorobenzene
acetic anhydride	Epsom salt (magnesium sulfate)	orthophenylphenol
acetylene tetrabromide	ethyl chloride	paradibromobenzene
acetylsalicylic acid	ethyl monochloracetate	paradichlorobenzene
ammonium bromide	ethylene bromide	paraphenetidin
ammonium salicylate	ethylene chlorbromide	paraphenylphenol
aniline hydrochloride	ethylene chlorhydrin	pentachloroethane
aniline oil	ferric chloride	phenol
anthralic acid	ferrous chloride	phenol salicylate
barium bromate	hexachloroethane	phenyl acetate
Bordo mixtures	hydrobromic acid	phenyl ethyl alcohol
bromoform	lead arsenate	potassium bromate
cadmium bromate	lime sulfur	potassium bromide
calcium arsenate	lithium bromide	propylene chloride
calcium bromide	lithium salicylate	purified bromine
calcium chloride	magnesium arsenate	salicylaldehyde
camphor monobrominated	magnesium bromate	sodium bromate
carbolic acid	magnesium bromide	sodium bromide
carbon bisulfide	magnesium chloride	sodium chloride
carbon tetrachloride	magnesium oxychloride	sodium salicylate
caustic soda	magnesium salicylate	sodium sulfide
chloracetyl chloride	methyl anthranilate	strontium bromide
chlorine	methyl bromide	strontium salicylate
chloroform	methyl salicylate	sulfur chloride
Ciba dyes (7 colors)	methylene chloride	sulfur monochloride
cinchophen	Midland Vat Blue dyes (3 types)	synthetic indigo
coumarin	mining salts	tetrachloroethane
dichloromethane	monobromobenzene	tetrachloroethylene
dichloroacetic acid	monochloroacetic acid	tribromophenol
diethylaniline	monochlorobenzene	trichloroacetic acid
dimethylaniline	nicotine sulfate	
diphenyloxide	orthocresotinic acid	

Source: Midland Sun (1926) and The Dow Chemical Company Product Catalog (1928)

Table 3-4 New Product Introductions during the 1940s, 1950s, and 1960s

The Dow Chemical Company

Decade	*Product*	*Production Years (where available)*	*Source*
1940s	1,1-dichloroethane	1945-1980	A
	1,2,4,5-tetrachlorobenzene	1945-1980	A
	2,4,6-trichlorophenol		
	2-(2,4-dichlorophenoxy)acetic acid (2-4-D; Dowspray™ 66; Esteron™ 44; Esteron™ 99; Esteron™ Brush Killer)	1945-1983	A
	2-chloropropionic acid	1949-1984	A
	4-chloro-2-phenyl-phenol (Dowicide™ 32)	1948-1972	A
	acrylonitrile		A
	alpha-methylstyrene		A
	antipyrene		A
	bromoform	1944-1983	A
	demethylaminobenzene		A
	dicyclopentadiene		A
	diethylbenzene	1946-?	A
	diisopropanolamine	1944-2000	A
	dinitro-o-sec-butylphenol (Dinoseb™, Premerge™, DN289™)		A
	methylchloroacetate	1947-2000	A
	propylene glycol		A
	sodium trichloroacetate	1948-1977	A
	toluene		A
	xylidene		A
	2,4,5-T (Esteron™ 245)	1950-?	A
1950s	4-chloro-2-cyclopentyl-phenol (Dowicide™ 9)	1965-1982	A
	1,2-dibromo-3-chloropropane (Fumazone™)	1957-1975	A
	1-methoxy-2-propanol (Dowanol™ PM)	1958-1990	A
	2-(2,4,5-trichlorphenoxy) ethyl 2,2-dichlorpropanoate (Erbon™)	1954-1979	A
	2,2-dichloroproprionic acid (Dalapon™)	1954-?	A
	2-chloro-1-morpholin-4-yl-ethanone (Morpholine™)	1950-?	A
	2-ethoxyethanol (Dowanol™ EE)	1957-1988	A
	2-methoxyethanol (Dowanol™ EM)	1957-1988	A
	acrylamide	1954-1971	A
	acrylic acid		
	bromobenzene	1950-1970	A
	bromomethylbenzene	1952-1976	A
	dimethoxy-sulfanylidene-(2,4,5- trichlor-phenoxy-phosphorane (Ectoral™, Trolene™, Ronnel™, Korlan™, Nankor™, Viozene™)	1957-1977	A
	Kuron™ herbicide containing 2,4,5-trichlorophenoxypropionic acid (also known as Silvex™)	1953-1980	A
	monoisopropanolamine	1953-2000	A
	o,o-dimethyl-o-(2,4,5-trichlorophenyl) phosphorothioate (Dowpon™, Ronnel™, Ruelene™)	1951-?	A

Table 3-4 ***Continued*** **New Product Introductions during the 1940s, 1950s, and 1960s**

The Dow Chemical Company

Decade	*Product*	*Production Years (where available)*	*Source*
	o-chlorophenol	1950-1965	A
	parachlorophenol		B
	p-dibromobenzene	1950-1968	A
	polyacrylamide (Separan™),	1950s-?	A
	SE-651	1958-1980	A
	styrene/butadiene latex	1950s-?	A
	Styrofoam™ brand plastic foam		B
	tetrachlorobenzene		B
	tetraethylene pentamine	1951-1966	A
	tetrasodium 2-[2-bis-(carboxylatomethyl)amon]ethyl-(carboxylatomethyl)amino]acetate (Versene™)	Pilot plant; 1951	A
	trichlorophenol		B
	Vidden™ (a mixture of dichloroprpenes and dichloropropanes)	1959-1983	A
1960s	(17-acetyl-6-chloro-3-hydroxy-10,10-dimethyl-1,2,3,8,9,11,12,14,15,16-decahydrocydopenta[a]phenanthren-17-yl)acetate (Verton™)	1962-1979	A
	(4-dimethylamino-3,5-dimethyl-phenyl methylaminoformate (Zectran™)	Pilot scale; 1961-1975	A
	2,3,5-trichloro-1H-pyridin-4-one (Daxtron™)	1965-1968	A
	2,4,5-T and 2,4-D mixture	1962-1970	A
	2-butoxyethanol (Dowanol™ EB)	1960-1988	A
	2-phenoxyethanol (Dowanol™ EP and Dowanol™ EPH)	1960-1967	A
	chlorpyrifos o,o-diethyl o-(2,4,6-trichlor-2-pyridyl)l (Dursban™)	Pilot scale;1965	A
	decabromodiphenyl oxide	1969-1986	A
	dimethylamine salt of 2-methyl-chlorophenoxyacetic acid	1963-1975	A
	Dowicil™ TBS	1962-1971	A
	l-isobutoxy-2-propanol (Dowanol™ PIB)	1962-1981	A
	methylene bromide	1960-1978	A
	o-2,4-dichlorophenyl-o-methyl isopropylphosphoramidothioate (Zytron™)	1960-?	A
	o-sec-butylphenol	1964-1979	A
	pentachloropyridine	1966-?	A
	pentachlorphenol (glazed, prilled form)	1965-?	A
	t-butylsalol	1966-1970	A
	tert-butyl-salol (TBS, Tausol™)	1963-1965	A
	tricyclohexylstannane hydrate	1967-1979	A
	triisopropanolamine	1966-2000	A
	Zetabon™ (coils of metal coated with ethylene copolymer plastic)	1965-?	A

Sources: (A) Birch, A. (2006) (B) ATS (2006)

4. CONCEPTUAL SITE MODEL

4.1 POTENTIAL SOURCES

4.1.1 Potential Dow-Related Historical Contaminant Sources

4.1.1.1 Wastewater Discharges

As previously described, the primary source of furans and dioxins from the Midland Plant to the Tittabawassee River is believed to be historic releases of aqueous wastes. The original chlorine manufacturing processes, which operated in the first part of the 20th century (see Historical Timeline Attachment F), are believed to be the most likely source of the comparatively high furan TEQ readings in and along the river. The furans would have been discharged directly to the Tittabawassee River. At the time of the wastewater discharge from the bleach production facility there was no wastewater treatment or any ability to detect the presence of either furans or dioxins. Lesser amounts of dioxins in more recent sediments are believed to be related to chlorophenol production beginning in mid-1930's. Over the many years of production at the Midland Plant, the wastewater discharges have changed in response to changes in the products and processes. Additionally, in that same time frame a number of activities have been undertaken specifically to reduce or eliminate releases of groundwater from beneath the Midland Plant which emerge at the Tittabawassee River, including closure of waste management units and outfalls, installation of the RGIS, and implementation of other release controls and monitoring programs as required by the License (MDEQ, 2003b).

On-site conditions and control of releases to the Tittabawassee River are being managed under the On-Site Corrective Action Program, and are not a part of this RIWP. Current inspection and monitoring activities are intended to identify any source control failures before significant releases to the river occur. Given process improvements, closure activities, on-site corrective actions, and ongoing monitoring requirements, there do not appear to be significant ongoing releases from the Midland Plant to the Tittabawassee River.

4.1.1.2 Groundwater Discharges

Historically there were a number of possible sources of contamination of the surficial sandy aquifer resting above the lacustrine and till clays. Today, these sources are controlled through a variety of physical containment and hydraulic capture and control activities including capping with rainfall permeation barriers (plastic or clay caps, or a combination of the two), slurry wall and sheet pile construction, and the RGIS system, which includes both perforated horizontal interceptor drains discharging to pumping sumps and groundwater capture wells. The location and description of the potential historic groundwater contamination sources were first comprehensively surveyed and described in a Dow report entitled "Report for Special Condition #8, NPDES Permit MI0000868 (Dow, 1991). This document has been periodically supplemented with status reports submitted to MDEQ that describe the progress of work over time to control these sources.

Figure 4-1 is an excerpt from the 1991 plan showing the locations of potential historic groundwater contamination sources, including the historic Poseyville Road Landfill (before modern licensing), Salzburg Road Landfill, the Tertiary wastewater treatment ponds, spent brine ponds, the historic 1925 Landfill located adjacent to the Tittabawassee River, the clay pits used for sludge dewatering and three sites having Locally Elevated Levels of Dioxin (LEL sites), which were locations of historic chlorophenol manufacturing operations or wastewater conveyance structures. Remedial investigations, corrective actions and monitoring of these areas along with other waste management units on the Midland Plant property are being conducted pursuant to License Conditions XI.C.

Today, the RGIS network of sheet pile, clay capping, horizontal interceptor pipes and groundwater capture wells controls the migration of contaminants away from these historic sources through a combination of physical and hydraulic barriers. The hydraulic barrier system works by reversing the groundwater flow along the river's edge such that there is a hydraulic gradient down from the river's water surface elevation into the lower elevation capture systems interior to the physical barriers. This reversal of groundwater gradient is continuously monitored along much of the length of the RGIS system, with periodic manual monitoring of a network of piezometer wells where the monitoring is not automated. Included among the License conditions are extensive requirements for RGIS system monitoring and performance reporting, along with proactive response requirements in the event of system performance failures.

During a routine inspection in 1994, MDEQ discovered that several of the piezometer wells indicated that the gradient reversal was no longer taking place along a section of the RGIS system. Subsequent investigation revealed that the horizontal interceptor piping through this section had become clogged with silt and this section of piping was replaced by Dow to restore the gradient reversal and the effectiveness of the RGIS system. Between the estimated initial time of failure and the restoration of groundwater gradient reversal, MDEQ estimated that a considerable volume of contaminated groundwater may have migrated to the Tittabawassee River. Table 4-1 lists the contaminants being found in the RGIS sumps at the time, which could in theory represent the contaminants likely to have existed in the groundwater discharges across the RGIS system during the period of failure. This list of contaminants is also likely to be at least qualitatively representative of the groundwater quality historically released from source areas along the river prior to installation of the RGIS system (MDEQ, 1994).

Presently the Dow On-site Corrective Action Program addresses the control of releases from the upland sources in the vicinity of the Midland Plant pursuant to License Condition XI.C. Part of this work is the investigation and control of migration through deeper sand layers interbedded within the underlying glacial till soils that may be connected to the Tittabawassee River, and monitoring under License Condition H.3 to assure that groundwaters at the perimeter of the Midland Plant are properly monitored.

To assure that contaminants that may have escaped the RGIS system would be included in the UTR site characterization, all substances observed in RGIS system monitoring have been incorporated into Target Analyte Lists for this project through the PCOI/COI/TAL evaluation process (see section 5.1.1).

4.1.1.3 Airborne Emissions

The historical waste management practices at the Midland Plant generated airborne contaminants in emissions from open burning and incinerator stacks, and in fugitive dust associated with uncovered waste stockpiles and construction activities. The Agin, et. al. Report (1984) provides a history of the incineration of liquid tars, and notes that incineration has been practiced at the Midland Plant since about 1930.

The primary source of furan and dioxin emissions to the atmosphere from the Midland Plant was incomplete combustion; either from waste materials containing furans and dioxins or of aromatic compounds that react with chlorinated organic compounds, chloride salts, and a metal catalyst (Agin, et al., 1984). Production of chlorinated phenolic compounds has also been associated with the formation of furans and dioxins, principally with production of the higher chlorinated phenols (tri-, tetra-, and pentachlorophenols) (Agin, et al., 1984). Other contaminants that could have been released though airborne emissions include VOCs, SVOCs, pesticides, PCBs, and metals. It is not possible to discern which specific source affected specific areas of the Midland study area. The 1984 Report concludes that, “Detailed analyses of past incineration practice, along with studies on the soils and airborne dust particles in the Midland area, show that historical dispersion of ashes and vent stack particulates from historical incineration operations are the probable source of the trace 2,3,7,8-TCDD levels now found in the local environment.”

4.1.2 Potential Non-Dow-Related Historical Contaminant Sources

Many potential contaminants, including VOCs, SVOCs, PCBs, metals, and pesticides, are common contaminants associated with commercial and industrial activities, and might not be attributed solely to operations at the Midland Plant. There are a significant number of commercial/industrial dischargers to the Tittabawassee River or its major tributaries. Current major point source dischargers to the river include the Midland Cogeneration Venture, the City of Midland WWTP, and the Saginaw Township WWTP. MDEQ water quality monitoring reports for tributaries upstream of Midland indicate that several WWTPs and various former industrial operations, including the Michigan Chemical Corporation, Velsicol Chemical Corporation, and Total Petroleum Inc., discharged to the Pine River. In addition, these same reports indicate a landfill, a WWTP and several industrial sites discharge to the Chippewa River. Therefore, it is possible that some contaminants in the Midland or Tittabawassee study areas may not be from the Midland Plant.

4.2 FATE AND TRANSPORT

Because of the hydrophobic and highly sorptive nature of chlorinated furans and dioxins, movement of these compounds within a riverine setting is typically dominated by the transport and deposition of solids. Soil and sediment transport processes include in-channel solids transport through the water column as bedload and suspended sediment, erosion and deposition of solids in the banks and floodplain, and exchange between the river channel and floodplain under flood conditions.

A summary of specific transport mechanisms that are relevant to the Tittabawassee and Upper Saginaw River systems is presented in the following sections.

4.2.1 In-Channel Sediment and Transport of Chlorinated Furans and Dioxins

The Tittabawassee River receives solids from the upper reaches of the Tittabawassee above Midland, and from the Pine and Chippewa River watersheds. The Upper Saginaw River receives solids from both the Tittabawassee River and the Shiawassee River and its tributaries, including the Cass and Flint Rivers. Under non-flooding conditions, these solids are transported primarily through the river channel as suspended material. These suspended solids may undergo some settling, deposition, and resuspension in the river channel, but suspended solids monitoring data collected to date suggest that the majority of suspended solids are simply conveyed through the Tittabawassee River and enter the Saginaw River at the confluence. In contrast, larger particles are typically transported via near-bed transport processes. The process by which larger particles (coarse sand and gravel) move along the sediment bed by rolling, sliding, and hopping is generally referred to as bedload transport. Bedload materials typically travel for relatively short distances before redeposition, followed by resuspension and further downstream transport.

The degree to which furans and dioxins are transported in surface water in dissolved-phase or adsorbed to suspended solids is not well understood. Previous studies of the transport of other hydrophobic constituents such as PCBs suggest that the majority of furan and dioxin transport in the Tittabawassee River, and probably the Saginaw River, likely occurs via suspended solids, while bedload transport likely accounts for a small fraction of total transport (Jude, et al., 1993).

The long-term behavior of the sediment bed in terms of its stability and role as a repository of furans and dioxins in the Tittabawassee and Saginaw Rivers is not fully understood at present. The occurrence of furans and dioxins at depth in the sediment bed suggests that mixing processes historically have been sufficient to move furans and dioxins below the surficial layer, but also that these mixing processes are occurring sufficiently slowly to allow the compounds to persist for some time once they make their way into the sediment bed. The sediment bed may also be affected by scour from winter ice formation and breakup. Ice-related factors that may affect the stability of the sediment bed include scour by individual ice flows, formation of ice jams, enhanced scour around or under ice jams, and overbank flooding.

4.2.2 Floodplain Erosion and Deposition

As part of the 2005 Scoping Study activities, CH2M Hill undertook field measurements of soil accretion using geochronology and dendrogeomorphology techniques. These methods produced estimated accretion rates ranging from 0.1-0.5 inches per year, with significant spatial variability (CH2M Hill, 2005c). This observed net accretion is the product of years of erosion and deposition processes that may have varied significantly in time and space. The expected effect of such processes on particle-associated furan and dioxin transport is a combination of periodic deposition of new solids from the river, and ongoing redistribution and mixing of furans and dioxins from the floodplain. The generally positive net accretion observed in the floodplain to date suggests that deposition and burial is a dominant process in the floodplain, resulting in the floodplain acting as a net sink of solids and associated furans and dioxins over time. However, future changes in erosion and redeposition may influence the present-day furan and dioxin distribution over time.

Riverbanks are a separate area of ongoing erosion, as indicated by the undercutting and sloughing of bank materials observed at several locations along the river. Bank erosion may contribute to the ongoing transport of furans and dioxins because of the potential for migration of these chemicals from the floodplain to the river due to bank retreat. This may be important in areas of bank erosion (that is, “cut banks”) that intersect former depositional areas such as natural levees.

4.2.3 River-Floodplain Exchange

Transport of solids between the river and floodplain (solids exchange) depends on the configuration of the river, local geomorphic features, and the amount of flow and solids transported during any given event. As described above, the Tittabawassee River channel at the north end of the Study Area is generally straighter, while the middle portion of the river is more sinuous. This is illustrated in the CH2M Hill Scoping Study Area 1 and Area 2 (for area delineation, see CH2M Hill, 2005c). In both areas, transport of solids between the river and floodplain occurs as the river flow leaves the main channel during flood events. In both the upstream and downstream portions of the river, this river-floodplain interaction results in the transport of some river sediment into the floodplain, creating formations such as natural levees and splays.

The 2005 Scoping Study on the Tittabawassee River included an investigation of floodplain soil characteristics including organic content, particle size distribution, and associated furan and dioxin concentrations (CH2M Hill, 2005c). Particle size distributions differ in the two areas. In Area 1, sandy materials predominate at most locations, with the exception of a line of more silty samples located on the inside of a shallow river bend. Higher TEQ concentrations appear to be associated with these silty samples, as well as with more sandy samples located in the natural levee area adjacent to the river. In Area 2, silty samples are more broadly distributed throughout the floodplain, and are generally associated with relatively high TEQ concentrations.

A comparison of the silty samples in both areas with estimates of their predicted streamline distances shows that most of these samples are at floodplain locations a short distance downstream from the river channel during flood conditions (that is, locations that have short streamline distances to the river under flood conditions). The observed gradient of relatively coarse sands in levee areas adjacent to the river and finer materials a short distance downstream in the floodplain is consistent with the sorting that would be expected during a flooding and sediment transport event. This suggests that transport of sediments from river to floodplain under flooding conditions may be a predictable phenomenon, and may also be a vector for historic and present-day transport of solids-associated furans and dioxins. The data available to date suggest that furans and dioxins may be preferentially associated with floodplain geomorphic features such as splays and levees that are formed by short-range sediment transport from river to floodplain. Elevated

TEQ concentrations observed across broader areas of the floodplain may be related to deposition of finer-grained suspended sediment transported greater distances from the river channel during flood events.

The sediment transport observations described above were supported by the “influencing factor” evaluation performed in the Scoping Study, which showed that streamline distance was the strongest predictor of TEQ concentration in the floodplain. The streamline distance serves as a simplified surrogate for the complex suite of processes that result in the erosion and transport of sediment particles, and subsequent redeposition in the floodplain. In general, low streamline distance implies a strong transport link to sediments in the river, and a greater probability of transport and deposition of river sediments to a given location.

As noted above and presented in more detail in Attachment E chlorinated dioxin and furan concentrations and thicknesses of deposited solids were measured in the Tittabawassee River floodplain after the March 2006 flood event. Total chlorinated dioxin and furan concentrations ranged from 25 - 5,120 ppt (TEQ), and the thickness of measured solids deposition ranged from zero to as much as 70 mm deposition. These findings will be integrated with the findings of an ongoing *GeoMorph*® study, to be issued in February 2007, relating dioxin and furan concentrations to geomorphological features of the floodplain. Conclusions concerning exchange between the river and the floodplain will be based on these multiple lines of evidence.

The transport processes to be evaluated in the RI work proposed in this RIWP are illustrated in Figures 4-2, 4-3, and 4-4, which display a conceptual model of solids movement in the Tittabawassee River, its floodplain, tributaries, and downstream waters. These processes include in-river transport of solids, exchange between river and floodplain due to processes that may include both overland flows during flood events and bank erosion, and deposition and/or erosion of the floodplain during flood events. Because of the hydrophobic nature of chlorinated furans and dioxins, these compounds associate strongly with solids in aquatic environments, and their presence in rivers and floodplains is highly dependent on the movement of solids between these environmental compartments. Estimates of solids and contaminant movement from water column, turf mat and clay pad studies will be integrated with the *GeoMorph*® characterization of floodplain deposits according to their geomorphological character to better understand the current inventories of chlorinated furans, dioxins and other COIs, and their potential exchange between river and floodplain.

4.2.4 Other Fate and Transport Processes

The available evidence indicates that chlorinated furans and dioxins are stable compounds under most environmental conditions (ATSDR, 1998). Photo-oxidation and photolysis of non-sorbed species may be significant environmental transformation processes for furans and dioxins. Photolysis appears to be a relevant fate process in the top few millimeters of surface soil, where ultraviolet light penetrates. However, after these compounds are incorporated into the soil there are no significant losses through volatilization or photolysis. Some photolysis also may occur in that portion of the water column where ultraviolet light penetrates. Furans and dioxins are considered relatively resistant to microbial biodegradation in soil. Some studies suggest that furans and dioxins in sediments may undergo anaerobic reductive dechlorination, in the same manner as has been observed for PCBs. However, if reductive dechlorination of furans and dioxins occurs under natural anaerobic conditions the reaction rates are expected to be low based on structure activity relationships for similar organochlorine compounds.

Another potential transport pathway for COI out of the floodplain that needs to be considered is the relocation of soils from the lower terraces of the floodplain to upland areas for use as fill materials.

4.3 HUMAN HEALTH EXPOSURE PATHWAYS AND RECEPTORS

The Human Health pathways and potential effects from exposure to PCDFs/PCDDs and other COI will be assessed in detail in the Human Health Risk Assessment (HHRA). The work planning for this assessment is included in Section 6 of this RIWP (see TR/USR RIWP Volume 2).

4.4 ECOLOGICAL EXPOSURE PATHWAYS AND RECEPTORS

In floodplain areas, PCDFs/PCDDs sorbed to soils present a potential exposure pathway to terrestrial organisms. Due to their very low water solubility and hydrophobic nature, the concentration of PCDFs/PCDDs in surface water is likely to be low and they are not expected to present a significant terrestrial ecological exposure route (Galbraith, 2004).

From floodplain soils, PCDFs/PCDDs move through the terrestrial food chain. Subsurface and surface invertebrates, for example earthworms, arthropods, and insects, accumulate PCDFs/PCDDs by direct contact and through ingestion. Higher trophic level organisms such as birds, moles, and shrews will ingest PCDFs/PCDDs as they eat the invertebrates. Herbivores such as rodents, rabbits, and deer accumulate PCDFs/PCDDs from eating the vegetation of the floodplain. Direct ingestion of soil present on the plant material is likely to be a more important exposure pathway than uptake from the plants themselves. Plants have very limited accumulation of PCDFs/PCDDs. Predators such as fox, coyotes, and raptor birds, will also consume PCDFs/PCDDs as their diet includes most of the groups described above. Due to their lipophilicity, PCDFs/PCDDs bioaccumulate as they move through the trophic levels.

A similar pattern exists in the aquatic environment. PCDFs/PCDDs partition onto the organic carbon fraction of the sediments, or are otherwise associated with sediment particulates. Sediment-dwelling benthic invertebrates, as well as fish will be exposed to PCDFs/PCDDs through direct contact and ingestion of the sediments. Higher trophic level fish that consume the benthos will also accumulate PCDFs/PCDDs. Fish-eating predators, both mammalian and avian, will be exposed as they consume fish. Although dissolved and particulate-adsorbed PCDFs/PCDDs may be present in the water column, and available for uptake by phytoplankton and zooplankton, "the majority of PCDFs/PCDDs that are passed up the aquatic food chain are likely to do so via the sediment-based dietary pathway" (Galbraith, 2003).

These pathways and potential effects from exposure to PCDFs/PCDDs and other COI will be assessed in detail in the Ecological Risk Assessments (ERAs). The work planning for these assessments is included in Sections 7 and 8 of this RIWP (TR/USR RIWP Volume 2).

5. FOCUSED INVESTIGATION APPROACH

This section provides the details of the Remedial Investigation that are relevant to the detailed site characterization of the Tittabawassee and Upper Saginaw River channels and floodplains. This section identifies the site characterization needs and presents a results-based approach for collecting the data to address those needs.

5.1 DATA REQUIREMENTS

Data needs for continued site characterization to meet the Remedial Investigation objectives identified in Section 1 of this RIWP are outlined below. The approach presented in this section has been designed to fulfill these identified data needs. Information collected during the implementation of the Remedial Investigation will be integrated into the CSM outlined in Section 4 in order to prepare a refined Site Model for the Study Area that will be presented in the Final Remedial Investigation Report in March 2009.

5.1.1 Primary and Secondary Constituents of Interest

The 17 regulated chlorinated dibenzofurans and dibenzodioxins used to calculate TEQ are the primary Constituents of Interest (COI) in this investigation. Certain furan congeners predominate in the mixture of dioxin-furan congeners present in Tittabawassee and Saginaw River sediments and floodplain soils downstream of Midland. Most of the Total TEQ is attributable to these furan congeners. As a result, a subset of selected furans and dioxins constitutes a useful suite of contaminants to assess the presence of sediment and soil impact. Because of the environmental fate and effects of these compounds, and their relatively low thresholds for environmental concern, it is likely that furans and dioxins will drive the ecologic and human health risk assessments.

However, because of the long and complex history of the Midland Plant as a manufacturer of chemicals, and the potential for additional contributors of chemicals to the Tittabawassee and Saginaw River watershed, other PCOI have been evaluated in a collaborative effort by Dow, ATS, MDEQ and USEPA. The evaluation process is described in detail in a Technical Memorandum prepared by ATS and submitted to MDEQ on December 1, 2006. This document, included as Attachment G, identifies the secondary COI substances in Target Analyte Lists (TALs) for near-plant and downstream portions of the TR investigation. These TALs, and their corresponding analytical method SOPs, have been incorporated into the project Quality Assurance Project Plan (QAPP). Secondary COI will be analyzed at a lesser frequency than furans and dioxins, on samples that are selected by Dow, ATS and MDEQ.

5.1.2 Constituents of Interest - Release History

Contaminant release histories constitute an important layer in the Remedial Investigation process. The potential periods of release for furans and dioxins from the Midland Plant have been established, as discussed in Section 4.1 above. Release histories for other potential or actual sources of constituents on the TAL will be established during the course of this investigation. Attachment F provides a historical Timeline summarizing relevant release history, prepared as an element of the 2006 *GeoMorph*® studies.

5.1.3 Sediment Geochemistry

Once released to the aquatic environment, chlorinated furans and dioxins, like other environmentally persistent, hydrophobic organic chemicals, would be expected to bind preferentially to sediment particles and, in riverine settings, move with those particles through natural erosion/transport/deposition processes. The capacity to bind such chemicals is largely proportional to surface area of the particles, and the binding energy is largely dictated by the surface chemistry. As a result, these hydrophobic chemicals are most often found where fine grained sediments occur, and preferentially when those particles are composed of significant carbon content (e.g. organic silts). Due to this preferential binding, it was originally expected that the furans and dioxins in the Tittabawassee River would be found where deposition of fine-grained sediments occurs. However, previous investigations have reported that furans and/or dioxins occur in unexpected sediment deposits, including those that are predominantly medium or coarse grained (CH2M Hill, 2005d).

Understanding the occurrence of furans and dioxins is fundamental to the *GeoMorph*® site characterization. Therefore, to resolve this surprising finding of furans and dioxins where they would not be expected, a Geochemistry Study is being conducted concurrently with the 2006 field survey to evaluate where, precisely, the chlorinated furans and dioxins occur in Tittabawassee River sediment fractions. Samples from selected locations are being analyzed for particle size distribution, particle density, and carbon content (organic, and “black” carbon). Furans and dioxins will be analyzed with individual congener concentrations and TEQ values reported for each isolated size fraction. The work plan for the Geochemistry Study, presented in Attachment H, was submitted to MDEQ for review and approval on June 29, 2006. MDEQ granted approval of the work plan on July 10, 2006.

5.1.3.1 Protocol Evaluation

To properly scope the analytical procedures for the Geochemistry Study, a Phase I Protocol was developed to evaluate the ability to adequately fractionate soil samples using both dry sieving and wet sieving techniques. The evaluation included the analysis of two archived soil samples from the Tittabawassee floodplain, containing elevated levels of furans and dioxins in the range of 5,000 to 25,000 ppt TEQ. These soil samples were fractionated into different size fractions, ("sand," "silt" and "clay") using standard methods of soil analysis (Day, 1965). The distribution of furans and dioxins in each fraction was determined, as was the organic and "black" carbon content. The findings of the Phase I protocol evaluation were summarized in a Technical Memorandum prepared by Dow and submitted to MDEQ on October 9, 2006. An important finding of the Phase I Protocol evaluation was that dry sieving did not give adequate separation of fine fraction and coarse fraction materials for the purpose of the Geochemistry Study.

5.1.3.2 Geochemistry Characterization of Select UTR Sediments and Soils

The Geochemistry Study protocol will be used to characterize a series of representative soil samples from the Tittabawassee floodplain during the implementation of the *GeoMorph®* SAP. The exact location and number of soil samples will be identified and reviewed with MDEQ during the implementation of the SAP. In general, sample locations will be representative of mapped geomorphic features, targeting four depositional features per selected reach(es) and collecting four samples per feature. The results of the Geochemistry Study will be reported prior to issuing the *GeoMorph®* UTR Site Characterization Report, so that the findings can be taken into account in the analysis of the contaminant distribution, transport and fate.

5.1.4 Surface Water Quality

As discussed above, once released to the aquatic environment, chlorinated furans and dioxins, like other environmentally persistent, hydrophobic organic chemicals, are expected to bind preferentially to sediment particles and, in riverine settings, move with those particles through natural erosion/transport/deposition processes. Surface water quality studies on the Tittabawassee River in 2005 and 2006 (see Section 3.2.1.3 and Attachment E of this RIWP) have demonstrated that storm events mobilize sediment particles into the river resulting in elevated furan and dioxin concentrations in the suspended solids within the river water. Moreover, the turf mat studies conducted in 2006 (see Section 4.2.2 and Attachment E of this RIWP), demonstrated that these particles are deposited in the floodplains during storm events and are contributing to the formation of fresh deposits of furan and dioxin to the floodplain soil surface.

In light of this information, the investigation approach presented in this RIWP defines the work needed to define the location and characteristics of the secondary sources of dioxins, furans and other COI stored in the river overbank that are contributing particulate-adsorbed contaminants into the water column during storm events. Future investigations will be focused on to identifying COIs deposited in the channel sediments and overbank soils.

5.2 FOCUSED INVESTIGATION APPROACH

5.2.1 Iterative *GeoMorph*® Investigation Approach For Site Characterization

GeoMorph® is a process developed in the last few years to address the longstanding and costly problem of removing contaminants in river sediments and their floodplains. The root technology of this process is geomorphology, which is the study of landforms on the surface of the Earth, and the processes that create and shape them. Fluvial geomorphology, a subspecialty profession, is the focused study of those landforms that are specifically created or influenced by moving water, such as rivers or streams.

The science of fluvial geomorphology has been used to define, characterize, map, and predict depositional and erosional areas on river systems ranging in size from small streams to the Mississippi River. A fluvial geomorphological characterization is the process of determining depositional and erosional environments within a river to understand the storage and transport of sediments through the river system. The geomorphic model of a river provides the foundation for the *GeoMorph*® process by guiding the sampling, data evaluation, risk evaluation, remedial design, and remediation implementation/residuals management.

The *GeoMorph*® process was developed by integrating geomorphologic concepts and risk analysis to river environments, and combining this with a practical approach to remedial design and implementation. The *GeoMorph*® process integrates three primary components: site assessment, imbedded risk review, and real-time (or near-real-time) fully validated analytical data from very carefully selected locations. *GeoMorph*® is used to identify areas of sediment deposition and erosion based on stream gradient, water velocity, thalweg location, sinuosity of the stream, and morphology of the floodplain and terraces. The process identifies similar sediment morphologies and focuses sampling to characterize these units. Remedial activities can then be evaluated by narrowly focusing on the sediment/soil deposits with the greatest risk. *GeoMorph*® is used to identify which sediment deposits should be addressed to yield the greatest environmental benefit and to make risk management decisions. When used in conjunction with the remediation activities, the risk analysis is enhanced with real-time data gathering in the post-remediation verification process. During remediation activities, field observations by trained scientists and the near real-time post-remediation concentration verification process assures a successful remediation without costly contractor delays or multiple mobilizations.

A fundamental element of the *GeoMorph®* site investigation approach to site characterization is that sampling activities are guided by near-real-time (NRT) feedback from the laboratory analyses. By having high quality data flowing back to the *GeoMorph®* Project Team on a NRT basis, sampling locations and depths can be adjusted or "iterated in the field" to assure that an adequate number of representative samples are collected and the nature and extent of COIs are understood before sampling crews demobilize from a study area. A series of statistical tools is integrated into the iterative process to aid decision making related to the adequacy of geomorphic feature and site characterization. The statistical tools are outlined in Section 5.4.5 and a Technical Memorandum describing the statistical approach is presented in Attachment I. The iterative process for the *GeoMorph®* site characterization is outlined in Attachment J and will be used throughout the implementation of the *GeoMorph®* SAP work on the Tittabawassee and Upper Saginaw Rivers.

5.2.2 Geomorphological Characterization

The *GeoMorph®* SAP for the Upper Tittabawassee River, approved by MDEQ on a pilot basis with limitations on July 12, 2006 and incorporated here by reference, describes the sampling strategy, sampling locations, and procedures to determine the horizontal and vertical extent of COI contamination in the upper 6 miles of the Study Area (ATS, 2006b). The depositional environments in UTR have been mapped and a sampling strategy presented in the UTR SAP to define the concentration and extent of COI in contaminated channel sediments and floodplain soils in the upper section of the river. The Middle and Lower Tittabawassee River depositional environments will be mapped by the end of 2006 and presented in the February 2007 Site Characterization Report. The depositional environments of the Upper Saginaw River will be mapped by the end of 2007. Pending approval of the February 2007 UTR *GeoMorph®* Site Characterization Report, a *GeoMorph®* SAP describing the sampling strategy and locations for the Middle reaches of the river will be prepared in the spring of 2007 and implemented in the summer and fall of 2007.

As discussed above, an Upper Saginaw River Scoping Study (USR Scoping Study) was submitted to MDEQ for review as a Conceptual SAP for the USR on March 1, 2006, and later resubmitted on March

24, 2006 as a Conceptual *GeoMorph®* Scoping Study (ATS, 2006a). The review of this document is being held in abeyance pending the results of the *GeoMorph®* pilot studies on the Upper Tittabawassee River. A site characterization SAP for the Upper Saginaw River will be submitted in early 2008. Dow's goal is to have the *GeoMorph®* investigations for the full length of the Tittabawassee River and the upper 6.5 miles of the Saginaw River completed by the end of 2008.

The purpose of the geomorphologic characterization is to determine the sediment depositional environments within the river channel, floodplains, and terraces of the rivers and understand the storage and transport of COI contaminated sediments and soils. This characterization is important to understand the history of the geomorphology of the rivers in particular as it relates to contaminated sediment deposition patterns in the last 100 years. Geomorphological characterization includes defining parameters that influence river system dynamics. The parameters include channel gradient, width, depth, sinuosity, bed material, discharge, water velocity, sediment load, sediment size, and anthropogenic influences. The geomorphological characterization of in-channel and overbank deposits is a multi-step process incorporating the results of the following investigation activities.

5.2.2.1 Topographic Mapping and Longitudinal Profile

The purpose of the detailed topographic mapping is to establish the longitudinal profile and sub-reaches of the river, compare the historic aerial photography to the present river configuration, and complete a preliminary mapping of the overbank floodplain and terraces. The purpose of the longitudinal profile is to determine changes in the channel gradient along the length of the river as one element of the geomorphological assessment. The changes in the channel gradient have an effect on the velocity and sediment deposition patterns in the river channel. The channel gradient can also affect the overbank sediment deposition pattern.

5.2.2.2 Determination of River Reaches

The changes in the channel gradient provide information about the reaches of the river. The channel gradient, channel width, channel bed material, and sinuosity are used to establish the breakpoints between the reaches of the river. A reach of the river is defined as an area of the river with a similar channel slope, channel width, channel bed material, and sinuosity. The reaches are important because the deposition pattern on like-geomorphic features will be similar within a reach.

5.2.2.3 Aerial Photograph Review

The historical aerial photograph review is conducted to determine the changes in the river, both man made and natural that affect the amount of lateral movement of the river over the period of interest. This historical perspective provides information about the changes in the deposition and erosion pattern of the river. This information is used to focus the sampling investigation on the areas of historic sediment deposition for the time period of interest defined for the study.

One of the first steps in the preparation of the *GeoMorph®* SAP for the Upper Tittabawassee River was to evaluate the aerial photo history from the confluence of the Chippewa River to the confluence of the Shiawassee River, and determine the availability and suitability of aerial photo coverage over the period of interest. Aerial photograph interpretation and geomorphic feature comparison at different points in time is a basic element, or "layer," of the *GeoMorph®* process and contributes to the "lines of evidence" evaluation. Aerial photographs reveal changes in river channel location along with the progressive development of natural and anthropogenic features. Aerial photographs have also been used along the Tittabawassee River to capture flooding events for use in calibration of storm frequency, river stage and floodplain extent.

A search for historical aerial photographs along the Tittabawassee River reveals a rich history of information. In 2004, Dow conducted a detailed review of available aerial photography. The aerial maps were placed in the GIS system as digitized versions of selected historical and recent aerial photography, along with historical USGS quadrangle maps, property boundary and zoning maps, soil characterization maps, and floodplain borders for various magnitude flood events. The GIS software employed is ESRI™ ArcMap™, as updated, a standard system regularly used by governmental units. All of the data within the GIS has been converted to the Michigan State Plane South (International feet) projection. All aerial photographic information entered into the GIS has been, or will be, ortho-rectified to correct for terrain distortion.

To supplement and confirm earlier work, ATS conducted additional searches of available historical aerial photographs and topographic mapping, and generated a list of available historical resources. The search work conducted during the preparation of the 2006 UTR SAP included:

- Available historical private and color topographic mapping dating back to the early 1900's by Environmental Data Resources, Inc. (EDR, 2006);

- Historical aerial photographs, in black and white, color and infrared from 1937 to 1993 (Intrasearch, Inc, 2006);
- Historical aerial photographs in the Dow Archives;
- Visits to the planning departments of Midland and Saginaw Counties and the City of Midland, and to the Natural Resource Conservation Service offices in both counties;
- Available historical aerial photos in the Michigan State University (MSU) Aerial Archives.

From these combined sources, ATS has selected the following shortlist of good quality aerial photographs that have complete coverage of the Tittabawassee River study area: 1937-1938, 1950, 1958, 1972, 1976, 1980-1982, 1986, 1998, and 2004. In addition to aerial photographs, early USGS topographic quadrangle maps were previously entered into the GIS for Saginaw County (1919, 1939, and 1941), and the St. Charles quadrangle (1917, 1943 and 1950). These aerial photo sets and USGS quadrangle maps were obtained and used in the development of the SAP and this RIWP. This series of photographs provide “snapshots” of the Tittabawassee River at roughly 10 year intervals for interpretation and comparative evaluation of river channel locations, geomorphic features, and a variety of natural and anthropogenic features. Previous experience has demonstrated that a 10 year interval is optimal for determination of historical meanders and lateral movement of the river channel. During the 2006 *GeoMorph®* investigation, ATS selected the most informative aerial photographs from this shortlist for digitizing, ortho-rectification, and entry into the GIS. The river channel will be digitized from the aerial photos for each of the chosen years. A graphical overlay of the various river channel locations over time will be generated and will aid in assessment of historical deposition areas and lateral movement trends.

The 1937-1938 series of aerial photographs along the Tittabawassee River represent the earliest aerial photo coverage of the study area. As an element of the work planning effort during the preparation of the 2006 *GeoMorph®* SAP, the 1937-1938 river channel alignment was derived using ArcGIS from a digitally ortho-rectified version of the 1937-1938 aerial photography stored in the GIS data base. This 1937-1938 alignment was then digitally superimposed on the 2004 aerial photography and is presented in the UTR SAP, which is incorporated by reference (ATS, 2006b). The information derived from this overlay was used to make an initial assessment of the lateral movement of the river channel over this 67 year period at selected transects and for the selection of the sediment and soils sampling locations. This initial river channel comparison overlay was reviewed with the MDEQ during the working sessions in May 2006 and will be included, among others, in the Site Characterization Reports.

To support the initial *GeoMorph®* sample location planning presented in the UTR SAP, a combined digital file of the 2003 LiDAR topography mapping and bathymetry from the April 2004 LTI channel poling study, including contours derived from the combined digital file, was superimposed on the 2004 aerial photography to generate the base maps used in the April 2006 field verification and mapping of geomorphic features. These maps were also used as the base mapping for the geomorphic features and proposed sampling location maps presented in the UTR SAP. A similar process will be conducted for the aerial photo-history of the Upper Saginaw River in 2007 and 2008.

ATS commissioned additional aerial photography of the Tittabawassee River and Upper Saginaw River study area in April 2006 to obtain the aerial photography necessary for the 6 inch accuracy needed to develop 1 foot contour intervals and to supplement and extend the aerial photo history. The ground control surveys needed for developing additional photo stereogrammetric topography mapping are being conducted on an as-needed basis to assist in defining the boundaries of geomorphic features.

5.2.2.4 Geomorphic Feature Mapping

The preliminary geomorphic feature mapping is conducted using the reaches of the river and the detailed topographic mapping to identify and map the geomorphic features of the river. The geomorphic features may include in-channel deposition areas, in-channel erosion areas, floodplain, low terraces, intermediate terraces, high terraces, and upland. For example, the deposition pattern is expected to be similar on the low terraces within a reach of the river. The deposition pattern is confirmed by a detailed soil and sediment profile analysis that is conducted during the implementation of the SAP.

To clarify the setting for a soil and sediment description location, the terms *floodplain* and *terrace* (*low, intermediate, and high)* are used in a relative sense and are not based on flood elevation determinations. The soil and sediment profile descriptions are used to confirm or change the pre-field determination of floodplain or terrace (low, intermediate, or high) terminology. Although the terms are not based on flood stages, the use of the term terrace (low, intermediate or high) relates to similar features within a designated reach, based on topography and soil/sediment profile descriptions. The proximity of one geomorphic feature to another feature is also evaluated for selection of soil and sediment description locations. For example, an intermediate terrace adjacent to the river channel is considered a different geomorphic feature than an intermediate terrace separated from the river channel by a low terrace.

5.2.2.5 Soil and Sediment Profiling

In a river environment, it is important to relate one feature area to another when evaluating depositional environments. Soil profiles are described and compared to determine if features have been influenced by similar depositional and/or erosion factors. Soil description locations are selected based on their setting in the river environment. The selection of soil description locations is based on parameters that influence the geomorphic feature including the channel gradient, channel configuration (e.g., meander versus straight), elevation, potential for sediment deposition, and thalweg location.

The in-channel sediment is the most dynamic portion of the river systems. The changes in water velocity, discharge, and sediment load and size due to seasonal and single event floods changes the erosion and deposition patterns of the in-channel sediments. Preliminary mapping and sampling of the in-channel sediments is necessary to obtain an understanding of the in-channel sediment conditions. However, detailed in-channel sediment mapping should occur as close to the desired corrective action as possible.

5.2.2.6 Geomorphic Polygons

Geomorphic polygons are graphic representations of individual geomorphic surfaces having homogenous characteristics defined using a variety of geomorphic indicators and which are used in developing the geomorphic feature mapping. They are developed by applying knowledge of the river geomorphology together with detailed topographic information and mapping of in-channel sediments for channel and overbank areas. In some cases geomorphic features may have one or more geomorphic polygons based on the complexity of the depositional and erosional pattern. Similar geomorphic polygons can be established based on the relationship of the overbank features to the river channel, erosion and deposition areas for in-channel areas, and contaminant distribution. The preliminary geomorphic polygons for the UTR are presented in the conditionally approved UTR SAP, which is incorporated here by reference (ATS, 2006b).

Geomorphic polygons are confirmed based on measured deposition and erosion characteristics. After geomorphic polygons are confirmed, the applicable risk factors associated with the contaminant(s) can be applied to areas with similar deposition characteristics. The field verification process includes the following tasks.

- Soil Profile Description
- Sediment Profile Description

- TAL Analysis of Soil and Sediment Samples

5.2.3 Surface Weighted Average Concentration (SWAC) Analysis

5.2.3.1 SWAC Methodology

A current condition Surface Weighted Average Concentration (SWAC) analysis will be performed for each geomorphic polygon of interest. This SWAC calculation will be prepared using the data collected from the SAP work to predict COI concentrations for the following geomorphic features:

- in-channel
- floodplain
- natural levees
- historic natural levees
- wetlands
- low terraces adjacent to the river
- low terraces away from the river
- low intermediate terraces
- intermediate terraces adjacent to the river
- intermediate terraces away from the river
- high terraces adjacent to the river
- high terraces away from the river
- upper high terraces adjacent to the river
- upper high terraces away from the river
- upland away from the river

5.2.3.2 Current Condition SWAC Process

The current condition SWAC for the TR/USR RI work will be developed by applying knowledge of the geomorphology of the river system together with detailed topographic information for the river and mapping of in-channel sediment to delineate boundary conditions for the flowing channel and overbank areas. "Like areas" will be established based on the relationship of the overbank features to the river channel. SWAC polygons will be assigned for "like areas" of in-channel deposits, floodplains or terraces based on their similarity as depositional environments.

The dynamic nature of the in-channel deposits requires a current sediment map. As part of the SAP for each section of the Tittabawassee and Upper Saginaw Rivers, preliminary sediment mapping will be completed to map the in-channel soft sediment deposits, non-soft sediment bottom (sand), and gravel/cobbles/boulders bottom. This will be produced graphically to illustrate the in-channel conditions. This map will be used to assign polygons for each distinct deposit type (i.e., soft sediment, non-soft sediment, and gravel/cobbles/boulders). For the TR/USR RI, a "distinct soft sediment deposit" definition will be established based on COI concentrations and related risk factors. Each in-channel soft sediment polygon will be assigned a COI concentration either from a sediment sample collected in that soft sediment deposit or a "proxy" value from a similar soft sediment deposit. Likely parameters used to establish similarity, and therefore suitability of a particular proxy value, include: relationship to meander bends, channel gradient, channel width, soft sediment texture, and proximity within a channel reach.

For in-channel areas with no soft sediment deposits or with soft sediment deposits smaller than the "distinct soft sediment deposit" threshold defined for this project, a "default non-soft sediment" concentration will be assigned. For the TR/USR RI this default value will need to be established based on measured values for hard packed sand. For in-channel portions of the river that have a channel bed consisting of gravel, cobbles, boulders or bedrock, a "default rock" concentration will be established and assigned. These "default" concentrations for non-soft sediment areas will be established and agreed upon.

The SWAC calculation used for overbank soil applies the soil concentration for the polygon to an assigned erosion factor (EF) reflecting potential to erode, an assigned attenuation factor (AF) based on proximity to the aquatic environment and other potential factors. If a sample concentration falls below the detection limit, one half of the detection limit will be used for the sample value. The adjusted concentration will be multiplied by the square footage of the polygon to obtain a "COI concentration times Area" number. The SWAC value is the sum of the adjusted "COI concentration times Area" numbers, divided by the sum of the Areas for a reach of the river, or for the entire river section. The total SWAC for each Reach will be calculated by summing the products of area and the adjusted concentration, divided by sum of all areas.

During the field investigation, the geomorphologic data, soil/sediment profile information, COI concentration data, and erosion potential data will be used to develop more accurate existing condition SWACs. The existing condition SWAC models will be updated on a near-real-time basis to optimize the sampling and analysis efforts prior to demobilization from the project area.

5.2.4 Fate and Transport Considerations

A thorough understanding of the forces and processes responsible for the exchange of COI impacted solids in the river systems is essential in the development of a scientifically sound remedial investigation. Additional data and evaluation tools will be developed in 2006 and 2007. This supplemental information will assist in: characterizing and modeling these processes; aid in the understanding of the movement and mobility of solids in the river system; adequately characterize erosion/deposition areas so that exposure risk can be properly evaluated; and establish confidence about the predictive abilities of the geomorphic model.

5.2.4.1 Hydrodynamic Model - Tittabawassee River

A two-dimensional hydrodynamic model of the Tittabawassee River, from its confluence with the Chippewa River to its confluence with the Shiawassee River, and including 1.25 miles of the Chippewa River upstream of the Chippewa/Tittabawassee River confluence, is being developed to provide an understanding and fine-scale simulation of the hydrodynamic forces that operate in the river channel and floodplain. The model is being developed using the Environmental Fluid Dynamics Code (EFDC) framework, an EPA modeling framework that has been applied at many riverine and coastal estuarine sites throughout the United States (Tetra Tech, 2002). The model allows for development of a curvilinear grid, making it possible to accurately represent the bathymetry of the Tittabawassee River channel and the topography of the shoreline and floodplain in detail, and to align the grid with the general direction of flow.

The two-dimensional EFDC model that is being developed is designed to provide a parallel line of evidence to the *GeoMorph®* study of sediment and floodplain contamination patterns, by simulating both dry-weather flow conditions (with and without periodic releases from the Sanford Dam), five significant, representative, and well-monitored flooding events that have occurred between 2003 and 2006 in the Tittabawassee river basin, and a simulation of the 1986 flood conditions. The EFDC model will simulate detailed water surface elevations, flows, velocities, and shear stresses for both in-river and floodplain areas of interest under these specific conditions. The model grid will have an average resolution of approximately 22 meters parallel to and 11 meters perpendicular to the dominant flow direction of the river and floodplain, which will allow for a detailed examination of how dry weather and flood events interact with geomorphological features and sampling locations. This detailed grid will provide the resolution needed to differentiate between characteristically erosional versus depositional areas under different river stage conditions, and to compare and integrate those results with *GeoMorph®* delineations, which are based on coring of in-river sediments and floodplain soils.

The two-dimensional EFDC model will also help to assess the degree of erosion risk present in areas of higher known contaminant concentrations, under dry weather flow and flooding events. The model will provide an estimate of how Tittabawassee River velocities and flow-generated shear stresses affect areas such as the outsides of Tittabawassee river channel bends, river bank levees, and wetlands and terraces within the Tittabawassee river floodplain. This will be done by determining the velocities and bottom-generated shear stresses throughout flood events, as simulated by the EFDC hydrodynamic model.

Proposed topographic or bathymetric changes to the Tittabawassee River and floodplain, due to alternative corrective action scenarios, can also be implemented within the current EFDC hydrodynamic model framework. Changes in velocity and shear stress at locations of interest and at secondary locations that may be adjacent to or downstream of the site of possible corrective action, can then also be predicted through use of the EFDC hydrodynamic model. In general, predicted fine-scale velocities and shear stresses will help to identify locations that would be relatively erosional or depositional, under each of the flow conditions simulated, and under a range of corrective action scenarios, while simulated flow paths from more erosional to more depositional areas will indicate possible paths of particle transport and accretion.

As of December 1, 2006, the following elements of the hydrodynamic model have been completed:

- the grid dimensions and grid spacing of the two-dimensional EFDC hydrodynamic model have been developed;
- bathymetry and topography have been assigned to each grid cell;
- upstream and downstream boundary conditions have been developed; and
- the model has been calibrated to low-flow conditions and six historical flood events, using water surface elevation and velocity data taken at several bridge locations, and the extent of flooding from aerial photos taken during the flood events.

Hydrodynamic results from the calibrated model will be delivered, along with the completed *GeoMorph®* study, in February of 2007. Hydrodynamic model deliverables will include:

- a technical memorandum describing methods and goodness of fit of the model calibration and final modeling results, including:

- peak velocity and shear stress figures for areas of interest under dry weather and flood flow conditions for current and alternative scenarios;

- figures depicting the extent of flooding for various flood flows; and

- figures depicting flow streamlines across the site for conditions and areas of interest for integration with *GeoMorph®* findings.

A similar numeric hydrodynamic model is under consideration for the Upper Saginaw River, and a final decision as to the need for numerical modeling in this part of the Study Area will be made in consultation with MDEQ in early 2008.

5.2.4.2 Particle Fate and Transport Numerical Model Simulations

Velocity and depth output data from the EFDC model discussed above will be used to support modeling of particle transport. Particle transport model runs will simulate the transport pathways and initial settling locations of particles of various diameters, inserted into the water column at selected locations under simulated dry weather and 2003-2006 flood flow scenarios.

Simulated starting points for particle transport will be based in part on EFDC flow path simulations, showing possible transport pathways between river, levees, and upland floodplain, and by *GeoMorph®* sampling results showing sediment and soil textures and contaminant levels at these locations. Results will be presented as downstream spatial distributions of settling locations, for particles "released" within a model simulation at a given location at fixed intervals under time-varying flow conditions.

Mapping of the spatial distributions of particle settling locations will be performed for release locations of interest for the five 2003-2006 flooding scenarios, including releases from locations that are predicted to be relatively erosional during alternative corrective action scenarios, based on EFDC local velocity and shear stress results. Deliverables will include a technical report describing:

- the particle tracking simulations performed, including discussions of scenarios simulated, assumed particle characteristics, and settling rates; and

- figures detailing the spatial extent of particle settling locations for the Tittabawassee River and floodplain, for all simulated release points, low-flow conditions and flood events, and corrective action scenarios of interest.

This report will be delivered along with the completed *GeoMorph®* study in February of 2007. EFDC will provide the hydrodynamic chassis for these simulations, which will begin once the hydrodynamic model runs of interest have been calibrated.

A similar numeric particle fate and transport model is under consideration for the Upper Saginaw River, and a final decision as to the need for numerical modeling in this part of the Study Area will be made in consultation with MDEQ in early 2008.

5.3 GEOMORPHIC DEVELOPMENT OF SAMPLING LOCATIONS

The following sections describe the process for the selection of Upper Tittabawassee River sampling locations from the City of Midland Tridge at Reach A to Orr Road near the end of Reach O. Geomorphic characteristics, a summary of previous investigation(s), and a description of the proposed sampling locations are provided for each reach in the conditionally approved UTR SAP incorporated here by reference. The topographic surface, 2004 aerial photography, and sample locations for each reach are provided in Figures 1 through 18 of Attachment E of the UTR SAP.

Sample locations for each reach in the UTR were selected based on both geomorphic feature and the overall channel setting. The geomorphic feature and the channel setting were considered for sample selection because fluvial transport and deposition are often correlated to these features. Each defined geomorphic feature was represented by sample location(s) that can be described in terms of the factors used in the SWAC analysis. The channel setting categories that were used to group geomorphic feature sample locations include the following:

- Adjacent to channel;
- Away from channel;
- Straight channel segment;
- Inside meander bend;
- Outside meander bend;
- Upstream or downstream of a bridge or culvert.

For the UTR, the geomorphic features were mapped from the City of Midland Tridge (Station 0+00) to near Orr Road (Station 320+00) on April 18-21. The river was segmented from Reach A through Reach O and the relative geomorphic features from upstream to downstream were described using LiDAR map data and either direct field inspection, when property access was possible, or best possible visual observation.

Geomorphic descriptive summaries for the reaches and the proposed sampling locations described by geomorphic feature and relationship to the river channel (adjacent or away) are presented in the approved UTR SAP and incorporated here by reference. Attachment B, Figure 2 in the conditionally approved UTR SAP presents the locations of the reaches for the Upper Tittabawassee River, downstream from the City of Midland.

A similar process will be followed for reach development and selection of sample locations in the SAP for the Middle and Lower Tittabawassee, which is to be prepared in early 2007, and in the SAP for the Upper Saginaw River, which is to be prepared in early 2008.

5.4 PROCEDURES FOR SITE CHARACTERIZATION

5.4.1 Sediment and Soil Sampling

In-channel sediment and over-bank soil sampling will be conducted to characterize soil profiles and establish COI concentrations. The methods to be used for in-channel and overbank sampling are summarized in Section 5.4.1.1 through 5.4.1.8. In most cases, the sampling will be conducted in transects perpendicular to the river. A transect may include in-channel samples and overbank samples to determine the depositional environment in that sub-reach of the river. For similar segments of the river, the data collected from these transect locations can be extrapolated upstream and downstream due to the geomorphic setting. The following procedures will be used for in-channel sediment and overbank soil sampling.

5.4.1.1 In-Channel Sediment Poling/Sampling

In-channel sediment poling is conducted to assess the location and extent of significant sediment deposits to determine the representative sample locations. In-channel sediment deposit thickness was previously characterized on the UTR by LTI in November and December, 2003 and again in April 2006 by ATS. Although this information is adequate for conceptual planning, an updated sediment inventory and preliminary sampling is required to determine the preferential deposition pattern of in-channel sediment, the sediment composition, and the contaminant concentrations. The preliminary sampling will provide data needed to design a sampling strategy that will be used in the future in advance of corrective action activities.

5.4.1.2 Sediment Inventory

The sediment inventory can be conducted in reaches having shallow water using chest waders and walking in the river channel during low flow conditions. However, deeper sections of the river and higher flow conditions will require the use of a sampling vessel. The sediment inventory will be conducted with a metal pole to measure the water depth from the water surface to the top of the sediment (recorded to the nearest tenth of a foot). The metal pole will then be pushed into the sediment until refusal. The total depth, minus the depth to sediment, yields an estimate of the sediment depth. This technique is adequate in this setting due to the underlying clay from the glacial lake bed or glacial till which will provide a refusal boundary.

5.4.1.3 Sediment Sampling

The in-channel sediment sampling will be conducted from the top of the sediment into the underlying native material (channel bed, lacustrine clay, clay till) unless refusal due to bedrock or some other physical obstacle is encountered. The water depth will be measured prior to sediment sampling at each location. Sampling will be conducted using chest waders (shallow water) or a sampling vessel (deeper water).

The sediment inventory data will be used to produce a map that describes in relative terms the type of river channel bottom. The channel bottom terms used include: soft sediment (silts and clays), sandy bottom, gravel bottom, or cobble and boulder bottom. The channel bottom types and relative shapes will be depicted on field maps for each reach by drawing polygons, which graphically represent "sediment deposits."

The sediment core sampler length will be determined upon completion of the sediment inventory. The sediment thickness will determine the length of the acetate liner. The acetate liner or sediment sampler will be advanced slowly into the sediment to minimize compaction. In some cases, such as sediment less than 1 foot thick with water depths less than 2 feet, the acetate liner may be pushed by hand.

Sediment profile descriptions are differentiated by color, texture, or unique features. Each sediment layer will be described by its sediment color (Munsell Color Chart), texture (USCS/Unified Soil Classification System; USDA-SCS/United Stated Department of Agriculture Soil Classification System), plasticity, cohesiveness, sand/gravel content, or unique features such as shell fragments, mottles, or organic matter. This information will be recorded on Sediment/Soil Core Data Forms.

The in-channel sample locations within a reach will be determined based on the variety of channel bottom types, dimensions, and relative distribution of each observed in the field. At least two samples will be collected from each sediment sample location: one sample of the overlying sediments, and one sample of the native material.

If the sediment illustrates distinct layering, discrete interval samples may also be collected based on the best professional judgment of the field sampling team leader. The interval for the sediment samples used for chemical analysis will be based on the sediment profile description and specifically distinct sediment layers. If the sediment is layered, samples will be collected from each layer to determine the COI concentrations in each sediment layer. If the sediment is homogeneous, the sample interval will be the entire sediment profile. At a minimum, a second sample will be collected from the native material.

Sampling location maps may show only one in-channel sample at a particular location. However, more than one sample location may be sampled based on the sediment inventory mapping and the channel bottom types. Gravel, cobble, and boulder bottom samples will not be collected as these benthic environments are difficult to sample and do not typically contain significant COI concentrations. A default concentration for these sample types will be established for these benthic environments.

5.4.1.4 Overbank Soil Sampling

Overbank soil sampling is conducted to determine the COI concentration extent horizontally and vertically for the geomorphic features within a reach. The horizontal extent is determined by the sample location, geomorphic feature, and the distance from the river. The vertical extent is determined by the soil horizon, contaminant concentration by depth, and presence of native material.

5.4.1.5 Overbank Soil Sample Collection

The soil sampling techniques used to collect the soil cores vary based on thickness of the soil core. For shallow soil sampling, less than 5 feet, it is anticipated that a hand operated stainless steel sampling tube with an acetate liner will be used. The sampling tube is driven into the ground using a deadblow hammer. A sampling tube is either 12 or 18 inches in length. For soils that cave in or for core depths greater than 5 feet, a Geoprobe® with casing and an acetate liner may be used for soil sampling.

A 1 foot stainless steel sampling tube with acetate liner will be used to collect samples for soil profile descriptions and for chemical analysis. After the sampling tube soil core is collected from a particular interval (e.g., 0.0 to 1.0 foot), a bucket auger will be used to auger down over the recently collected interval so the soil tube with a new acetate liner can be used to sample the next interval, without interference from the sidewall of the previous interval.

5.4.1.6 Soil Profile Descriptions

Soil horizons are determined based on pedogenic processes or vertical or lateral accretion sediment deposition characteristics. A soil profile description will be completed for each horizon. The soil profile description includes soil color (Munsell Color Chart), USCS soil texture, USDA-SCS soil texture, moisture, organic content, mottling, clay skin development, and other soil features such as the presence of shell fragments, sand or gravel lenses, iron concretions or odors. The soil profile description will be recorded on Sediment/Soil Core Data Forms. Soil profile descriptions will be completed to the depth of the native soil horizon.

5.4.1.7 COI/TAL Sampling

Following completion of the soil profiles, sample intervals will be selected for chemical analysis based on geomorphic setting and soil horizons. Although soil cores will be obtained in 1-foot intervals, the sample interval specified for chemical analysis will be selected based on the soil horizons. Samples will be collected by soil horizon to determine the extent of impact.

5.4.1.8 Erosion Scar Sampling

The erosion of contaminated soil into the Tittabawassee River from the river banks may re-mobilize COIs into the river. Erosion scars along the river banks are observable in areas where erosion is being caused by high river velocities and shear stress along the river bank face during storm events, or from undercutting of river banks due to daily river level fluctuations. The erosion scar face represents the soil present in the feature deposit that has not eroded but has been disturbed through the erosion process. Data collected from the erosion scar provides information on soil that has the potential to erode into the river, but is difficult to relate to the depositional or geomorphologic features. This information is valuable for identification of potential re-mobilization to the river, but this information should not be used to interpret geomorphic features.

Erosion scar sampling will be conducted following characterization of the adjacent geomorphic feature that is being eroded. The vertical profile of the adjacent geomorphic feature will include soil horizon determination, soil profile descriptions by soil horizon, and analytical data based on the soil horizons. The results of the soil profile description and analytical data will provide information on the contaminant concentrations within the soil horizon. Based on these data, select erosion scar locations may be sampled. Erosion scar samples will be collected using an acetate liner pushed horizontally into the river bank to a depth of 6 inches.

5.4.2 Decontamination and Sample Handling

At a minimum, all non-disposable and non-dedicated sampling equipment will be decontaminated prior to initial use, between sample intervals, and between sampling locations. Equipment decontaminated prior to field use will be stored in a sealed plastic bag to prevent contamination. All equipment used in sampling, including stainless steel bowls and utensils, will be decontaminated by washing with a laboratory grade soap solution, and triple rinsing with water (tap water followed by two deionized or distilled water rinses) and air-dried. Decontamination water will be collected and containerized for proper disposal.

Samples will be packed on ice, delivered to and/or shipped via overnight courier to the laboratory. The applicable laboratories will analyze the samples for target furans and dioxins using USEPA 1613-TRP/RT. The furans and dioxins analysis will have a fast turnaround from sample collection to availability of results. This rapid analytical turnaround will allow the sampling team to collect additional step-out samples as warranted, to define in near-real-time the vertical and horizontal extent of contamination prior to demobilization from the project area. Decontamination and sample handling procedures are described in the UTR QAPP, which is incorporated here by reference.

5.4.3 Sample Location and Field Positioning

All sample locations will be staked and/or surveyed during the project to the extent practicable using a Real-Time Kinematic Global Positioning System (RTK/GPS) and/or Differential Global Positioning System (DGPS), with a coordinate accuracy of +/-1 meter (x, y), and vertical control of +/-0.5 foot msl. The horizontal coordinate system shall be the Michigan State Plane Coordinate System, South Zone, NAD 83, in international feet. The vertical datum shall be NAVD 88. In some cases trees or other obstructions may interfere with RTK/GPS or DGPS signals and require survey by Electronic Total Station or measurement from landmarks clearly visible on the site topographic maps. If an unreasonable horizontal error is found, outside +/-1 meter accuracy, a registered surveyor will be used to reconcile the discrepancy. Sample location and field positioning procedures are detailed in the UTR Project QAPP.

5.4.4 Field Documentation and Recordkeeping

5.4.4.1 Field Sample Data Collection Forms

Field data forms will serve as a daily record of events, observations, and measurements during all field activities. All information relevant to sampling activities will be recorded on these forms. Entries on these forms will include:

- Names of field crew
- Date and time of site entry and exit
- Location of sampling activity
- Sampling method
- Number and volume of samples collected
- Date and time of sample collection
- Sample identification number
- Field measurements
- Field observations

Complete forms will be maintained for quality assurance purposes. As appropriate, field Quality Assurance corrective actions will be recorded in field data forms, memos, or in the Corrective Action Logbook maintained for the project. These records will become part of the permanent project file.

5.4.4.2 Chain of Custody and Shipping

Field personnel are responsible for the care and custody of samples until they are transferred or shipped. As few people as possible should handle the samples. Field personnel will complete sample labels and chain-of-custody forms in waterproof ink, at the time of collection. The label will include the project number, unique sample identification number, date and time of collection, and type of sample. All samples will be placed on ice in the field to keep them cool and throughout packaging and transport. When transferring possession or shipping samples from the UTR project, the individuals relinquishing and receiving will sign, date, and note the time on the chain of custody form.

Samples will be properly packaged for shipment in strong, tamperproof containers that are uniquely identified. The containers will be secured with strapping tape and with signed and dated custody seals. Samples sent by commercial carrier will include a bill of lading with a unique record number for computer tracking of the shipment. This tracking number will be recorded as part of the permanent custody documentation. Commercial carriers are not required to sign off on the custody record provided the custody forms are sealed inside the shipping container and the custody seals remain intact.

Upon receipt of the samples at the laboratory a Sample Receipt Form (SRF) will be completed in addition to the chain of custody record. The SRF will document the condition of the chain of custody seal and the samples at the time of receipt. It will also list the laboratory storage location for the samples.

5.4.5 Statistical Calibration and Verification of *GeoMorph®*

A principle of the *GeoMorph®* sampling design is that there is an association between the variation in furans and dioxin concentrations in the floodway soils and their locations in distinct fluvial deposition areas. This is based on the relationship between fluvial systems and sediment deposition which is best characterized by geomorphologic principles and fluvial processes. The *GeoMorph®* sampling design is based on collecting representative soil samples from distinct fluvial geomorphic features to characterize the furan and dioxin concentrations associated with the soils from these geomorphic features.

MDEQ has expressed its desire to statistically calibrate and verify the *GeoMorph®* process sample design by comparing the efficiencies and results generated by the *GeoMorph®* process to that of random on grid and fixed interval sampling designs. In general, standard statistical protocols will be applied to select the most appropriate statistical test(s) based on evaluations of the dataset(s). The evaluations will consider a number of variables including the number of data values, satisfaction of normal distribution model assumptions (independence, normal distribution), and potential influence of outliers on data analyses to select the most appropriate parametric and/or nonparametric statistical tests.

During the course of the TR/USR RI work, four separate procedures will have been used to support and validate the *GeoMorph®* sampling design.

- The first procedure evaluates the assumption that part of the variation in the concentrations of furans and dioxins in floodway soils can be explained by accounting for fluvial deposition areas in the floodway;

- The second procedure will be utilized to evaluate outliers in furan and dioxin concentrations within geomorphic features during the field activities so that these outliers can be addressed in a consistent and timely manner;

- The third and fourth procedures compare the results from biased *GeoMorph®* sampling design to both fixed interval and random on grid sampling designs.

The first two procedures will be used to evaluate all *GeoMorph®* sampling results generated during the implementation of this TR/USR/ RIWP. The third procedure, comparing *GeoMorph®* sampling design with a MDEQ-specified fixed interval sampling design is being undertaken during the 2006 UTR sampling and analysis work. The fourth procedure, comparing a *GeoMorph®* sampling design to a random on grid design (in Study Area 1 of the 2005 Scoping Study) is also being undertaken in the 2006 UTR sampling and analysis work. The results of both of these later two comparative studies will be presented in the February 1, 2007 UTR Site Characterization Report.

Additional comparisons between the *GeoMorph* sampling design and random on grid sampling designs will be conducted in locations where previously generated datasets are available (Scoping Study Areas 2 and 3 and the confluence area) and/or in collaboration with MDEQ where additional statistical confidence is necessary, for sampling and analysis of Priority I and Priority II properties.

The statistical calibration and verification of *GeoMorph®* will be an ongoing process throughout the implementation of the SAPs. The following sections provide an overview of the statistical tools that will be utilized as part of the *GeoMorph®* SAPs to assess the adequacy of site characterization. The Technical Memorandum that describes the statistical and calibration approach is included in Attachment I.

5.4.5.1 Screening for Outliers in Geomorphic Features

Abnormally high and low concentrations of furans and dioxins in a geomorphic feature will be identified and addressed during the field activities. Identifying and addressing these outliers early and during the active field period will improve the quality and coverage of the final dataset generated on the UTR project. Knowledge gained from the UTR pilot work will be applied to subsequent work on the Middle and Lower Tittabawassee River and Upper Saginaw River.

Initially, the furan and dioxin concentrations from each geomorphic surface within a given reach will be screened for outliers. A graphical evaluation of each population (i.e., each geomorphic feature and similarly mapped geomorphic features within a given reach) will be performed to look for potential outliers and to evaluate the assumptions about the distribution of the data required for analysis of variance (ANOVA) and required for the outlier test described below. The data and log transformed data will be separately represented in box plots and probability plots. The distribution of data in each population will be evaluated from these plots. Each dataset will be evaluated for both normal and lognormal distributions. The results of these evaluations will be compared to determine which distribution provides a better fit to the data.

After initial screening, a formal test will be performed if the presence of one or more outliers is suspected following the procedures in the statistical training material provided by the MDEQ Sampling Strategies and Statistics Training Materials for Part 201 Cleanup Criteria (S3TM) (MDEQ, 2002b; Section 2.1.4). If only one outlier is suspected based upon the graphical representation, then Grubbs' test will be utilized. If multiple outliers are possible based upon the graphical representations, then Dixon's Test will be used if the sample size is equal to or less than 25, and Rosner's test will be utilized for sample sizes larger than 25.

These tests will be utilized when there are at least four detectable concentrations in the population. If there are less than four detectable concentrations in the population, only graphical methods will be used to evaluate possible outliers. Censored data (not detectable concentrations) will be addressed using the procedures presented in the section on ANOVA. Prior to performing Dixon's Test, the data distribution will be evaluated graphically. If the data are assumed to be normally distributed, then the un-transformed data will be utilized. If the data are assumed to be log normally distributed, then the data will be log transformed prior to use in tests.

All data that are identified as outliers will be evaluated. S3TM (MDEQ, 2002b; p 7.42) provides the following partial list of possible causes for outliers:

- errors in sampling, laboratory analysis, data entry, or transcription;
- an accurate result sampled from a different population;
- an accurate but extreme value from the original population;
- an accurate value that appears to be extreme because of failure to obtain a representative sample, due to insufficient number of samples or biased sampling.

In consideration of the need to evaluate each outlier or set of outliers identified, one of the following actions will be taken:

1) Laboratory records will be reviewed for possible errors in analysis, data entry, or transcription.
2) The geomorphic feature will be evaluated to determine if field data support the conclusion that there may be more than one feature present. If there is supporting

evidence to re-classify part of the geomorphic feature, then the geomorphic feature may be re-defined or split into multiple features to address the data generated from the study.

3) The outlier may appear to accurately represent the variation within a geomorphic feature, and the outlier may be accepted as part of the geomorphic feature.

4) Additional soil samples may be collected and analyzed to further evaluate and delineate the outlier within a mapped geomorphic feature.

Performing the outlier evaluation at a 95 percent level of confidence (i.e., $\alpha = 0.05$), it is expected that one out of every 20 comparisons will identify an outlier even if there are no outliers present in any dataset. Furthermore, when testing for multiple outliers (potentially three outliers evaluated in every dataset), the potential frequency of falsely identifying outliers increases. There are 15 reaches being evaluated, and there are typically more than six features in each reach. Therefore, it is expected that over 100 comparisons will be made. With this number of comparisons, it is expected that multiple tests will falsely identify an outlier when one does not exist. In addition, the outlier test assumes normality. With the small datasets that will be tested, we will not be able to provide a statistically robust test of this assumption. Some populations will likely not be normal or lognormal. The expectation that distributional assumptions will be incorrect in some cases increases the probability of falsely identifying an outlier when no outlier actually is present. Therefore, not all outliers will be eliminated from the dataset, but each outlier will be reviewed with the MDEQ, and addressed in the final report. The outlier evaluation is included to screen the analytical data and to focus additional sampling and field mapping activities within the *GeoMorph®* sampling program.

5.4.5.2 Evaluate GeoMorph® Stratification

Through the course of the proposed work, soil borings will be set at hundreds of sample locations and thousands of soil samples will be analyzed for furans and dioxins. Each of these sample locations will be specifically tied to a geomorphic feature as well as other aspects that describe the sample location such as a distance from the river bank, a distance from Midland, and an elevation. Initially, an ANOVA will be performed to determine whether geomorphic features explain a significant amount of the variation in the furan and dioxin concentrations. The S3TM (MDEQ, 2002b; p. 4.25) supports the use of ANOVA to evaluate if “analytical results differ significantly among strata”, and whether use of the strata are “necessary and statistically valid.”

ANOVA will be conducted on a subset of furan and dioxin congener concentration data of greatest quantitative significance for characterizing extent and distribution of impacts and for risk assessment.

The distribution of concentrations within each *GeoMorph®* stratum will be evaluated for consistency with normal or lognormal distributions, to determine whether it is more statistically appropriate to perform ANOVA on concentrations or the logarithm of concentrations. The prevalence of non-detects (censored data) and outliers will also be addressed, as described below in this section. If the dataset(s) do not support the assumption of a normal or lognormal distribution, then a nonparametric statistical comparison may be utilized to evaluate the variation in the furan and dioxin concentrations. The detailed statistical procedures are described in a Technical Memorandum, included in Attachment I.

5.5 DATA QUALITY OBJECTIVES AND REQUIREMENTS FOR SITE CHARACTERIZATION

5.5.1 Project Data Quality Objectives – *GeoMorph®* Investigation of Contaminated Soils and Sediment

The purpose of the *GeoMorph®* SAPs is to define a plan for an optimized, geomorphology-based investigation that will result in a site characterization sufficient to support the evaluation and selection of risk management options in the river channel sediments and floodplain soils. The project Data Quality Objectives (DQOs) outlined in this section form the fundamental objectives for the investigative plan outlined in detail in Section 5. The type and quality of data needed to address the project DQOs are also identified to address potential problems before sampling and analysis begin. The selection of COI/TAL constituents and statistical approaches that will be used to evaluate data generated from the *GeoMorph®* investigations are described in Attachments G and I respectively.

5.5.1.1 Project Data Quality Objectives Process

The DQO process is a planning tool used to ensure that only that data needed to support the risk management decision-making process is collected, and to ensure that data of sufficient quality and precision are collected so that informed decisions can be made. An important element of the *GeoMorph®* investigation approach is that sampling activities will be guided by near-real-time (NRT) feedback from the laboratory analysis work to ensure the adequacy of the data in satisfying the DQOs. The laboratory validation and quality control processes built into the laboratory procedures (as described in Project QAPP) will assure the quality and precision of the laboratory data, and will serve the needs of the DQOs. By having high quality data flowing back to sampling personnel on a NRT basis, sampling locations and depths can be adjusted or iterated in the field to assure that an adequate number of representative samples are collected and the nature and extent of COI constituents are understood before sampling crews leave the field. The iterative process structure for the *GeoMorph®* site characterization is outlined in Attachment J and will be used throughout the implementation of the *GeoMorph®* SAP.

5.5.1.2 GeoMorph® SAP Data Quality Objectives

The USEPA guidance document, *Guidance for the Data Quality Objectives Process* (USEPA, 2000) was used in formulating the following DQOs for *GeoMorph®* SAP activities. The principal objectives for data gathering during *GeoMorph®* investigations are defined as follows:

1) Identify the COIs that may have been released to the Tittabawassee and Saginaw Rivers from historical operations at The Dow Chemical Company (Dow) Midland Plant;
2) Identify Near Plant TAL and Downstream TAL, which will be subsets of the COI list, based on evaluation of environmental fate and transport, persistence, toxicity, and other relevant factors;
3) Conduct rapid turnaround laboratory analysis of furans and dioxins to address a threshold for environmental concern of approximately 100 ppt TEQ. Individual furan and dioxin congeners will be quantitated to a level at or below 10 ppt TEQ, yielding a reporting limit for the aggregated congener concentration of 50 ppt TEQ or less. Therefore, depending on the particular purpose, these data may be useful for environmental evaluations substantially below 100 ppt TEQ;
4) Characterize the distribution of COI in in-channel sediment and floodplain soils based on the geomorphic model, as follows;
    a. Provide information on the horizontal and vertical distribution of furans and dioxins and other COI in in-channel sediment;
    b. Characterize the horizontal and vertical distribution of furans and dioxins and other COI constituents in floodplain soils;
    c. Characterize the impacts of anthropogenic features on the deposition and scour of furans and dioxins and other COI constituents;
5) Characterize the distribution of furans, dioxins, and other COI constituents across soil and sediment characteristics of interest, such as soil type, grain size and density, carbon content and type, and location within “like-character” geomorphic features, and distance from the river channel;
6) Characterize the fate and transport mechanisms and develop predictive tools for the soil and sediment fractions of interest and associated COI constituents in the river and floodplain to support evaluation and selection of risk management options;
7) Identify areas of the rivers and floodplain acting as secondary sources for downstream transport of COI constituents that may be candidate areas for early or interim response activities, pilot

study activities, institutional controls, and/or further investigations;

8) Identify areas of the floodplains where ongoing accretion of clean soils will isolate soils contaminated with COI constituents in a reasonable period of time, as well as those areas where accretion rates need to be supplemented with other risk management options such as institutional use controls, thin soil capping or other risk management options;
9) Collect samples that represent environmental media (soil and sediment) and the related conditions to support the following activities;
    a. Human Health Risk Assessment Work Plan Activities (HHRA);
    b. Ecological Risk Assessment Work Plan Activities (ERA);
10) Collect samples that represent environmental media (soil and sediment) and the related conditions to support public information and participation activities.

5.5.2 Level of Quality Effort for Site Characterization Work

The overall QA/QC objective during the TR/USR RI site characterization work is the use and implementation of procedures for sample collection, field documentation, sample custody, analytical methodology, field and laboratory QA/QC, and reporting that provide results which are legally defensible and based on sound engineering and science. The overall QA/QC objective of the laboratory analytical program is to generate data that is scientifically defensible and of known precision and accuracy. Laboratory DQO for the RI, expressed in terms of precision, accuracy, and completeness are given in the UTR QAPP. Field DQOs for the TR/USR RI are summarized in Section 5.5.3.

5.5.3 Field Quality Objectives for Site Characterization Work

Sampling precision and bias will be assessed through the collection of field duplicate samples. In general, 1 field duplicate and 1 field blank per 20 environmental samples or a minimum of 1 per sampling event will be submitted to the laboratory. The variation between field duplicate results should be no greater than ±20 percent for conventional parameters and ±35 percent for organics. Duplicates with Relative Percent Difference (RPD) values in excess of these limits may be indicative of imprecision resulting from sampling techniques and results should be evaluated accordingly. Steps will be taken to correct potential sources of imprecision for any additional sampling but in these cases re-sampling will not occur. Accuracy in the field will be assessed by analysis of equipment blank rinsate samples. Equipment rinsate blanks which consist of deionized water rinsates of sampling equipment or containers will be analyzed to indicate potential sample contamination from contaminated equipment. At least one equipment rinsate blank will be taken per sampling event.

5.6 QUALITY ASSURANCE PROJECT PLAN FOR SITE CHARACTERIZATION WORK

A Quality Assurance Project Plan (QAPP) was developed by ATS for the UTR site characterization work. The UTR site characterization QAPP includes information on project organization, responsibilities, sampling procedures, quality control checks, data management, and reporting. The QAPP will be updated annually based on the work to be performed in subsequent sections of the Study Area. The QAPP is incorporated into this document by reference.

5.7 HEALTH AND SAFETY PLAN FOR SITE CHARACTERIZATION WORK

A Health and Safety Plan (HASP) was developed by ATS for the UTR site characterization activities. The HASP includes safety precaution information and emergency procedures. The HASP will be updated annually based on the work to be performed in subsequent sections of the Study Area. The HASP is incorporated into this document by reference.

6. HUMAN HEALTH RISK ASSESSMENT – (SEE TR/USR RIWP VOLUME 2)

7. SCREENING LEVEL ECOLOGICAL RISK ASSESSMENT – (SEE TR/USR RIWP VOLUME 2)

8. BASELINE ECOLOGICAL RISK ASSESSMENT – (SEE TR/USR RIWP VOLUME 2)

9. CURRENT AND FUTURE INVESTIGATION WORK

9.1 2006 AND 2007 INVESTIGATION WORK

9.1.1 RIWP Review and Approval Approach

The review and approval approach for this RIWP will follow the same approach employed for the UTR SAP. In September 2006 the MDEQ was provided and had an opportunity to comment on early drafts of the Table of Contents (TOC) for this RIWP, and their comments have been taken into account in the drafting of this RIWP. A near final draft of this RIWP was submitted to MDEQ and USEPA on November 1, 2006 and a series of "pre-submission" meetings/teleconferences were held beginning on November 2, 2006 to allow MDEQ and USEPA an opportunity to review and comment on early drafts prior to the formal submission of this RIWP on December 1, 2006.

Subsequent to formal submission, a series of scheduled collaborative working sessions will be held between MDEQ and Dow consultants to review and resolve any remaining concerns, comments and conditions by way of revisions, addendums or conditions of approval. The schedules in Section 10 of this RIWP show a 30 day period of review by MDEQ to allow early planning and an early start on the aggressive program of site characterization work scheduled for 2007. Key project elements including risk management decision points have been assembled graphically on the Gantt chart in Figure 9-1.

9.1.2 UTR *GeoMorph®* Mapping, Sampling and Analysis and Multiple Lines of Evidence Approach

Upon the completion of the UTR SAP work in the fall of 2006, the findings from the field and laboratory efforts will be reduced to tabular and graphical forms to facilitate interpretation of the data. The maps will include depictions of the TEQ data projected as lines of equal concentration as well as geologic cross-sections with vertical concentration profiles. These tabular and graphic presentations of the data will serve as one layer in a "multiple lines of evidence" approach along with the following additional layers:

- Evaluation of contemporary and historical aerial photography to track the movement of the river channel with time, and to assess the impacts of anthropogenic changes such as bridges and constructed drains across the floodplains to allow historic wetlands to be used for agricultural purposes.

- River water quality, turf mat, clay pad, dendrogeomorphic and bed and bank erosion surveys completed in 2005 and 2006 relating to the transport and deposition of river sediments in the floodplains.

- Field observations during the performance of the 2006 UTR SAP relevant to the history. For example; the presence of burnt and un-burnt wood in the levee soil profiles related to the late logging era in the late 1800's; apparent layers of calcium and iron-rich deposits related to the early years of the chlor-alkali operations at the beginning of the 20th century; and black flecks present in certain soil horizons possibly related to the arc-rod carbons used throughout the early history of the Midland Plant operations; the 1925 construction of the Sanford Dam related to the narrowing of the TR channel and the formation of new natural levees interior to the historic levees typically found farther back on the overbank.

- Numerical hydrodynamic modeling and particle transport simulations to confirm fluvial geomorphologic delineation of the erosion and deposition zones in the channel and floodplain, and the likely performance and secondary impacts of alternative corrective action scenarios for selected portions of the river and floodplain.

- COI distributions as they relate to the period of release and Midland Plant production operations occurring at the time of release.

- Geochemistry fractioning and settling measurements.

All of these layers will be assembled during the *GeoMorph®* site characterization process. The results of these evaluations will be used to complete the site characterization of the UTR, develop the Surface Weighted Average Concentration (SWAC) for each geomorphic polygon; identify areas of priority concern due to COI concentration and risk of erosion, develop remedial action objectives and evaluate corrective action alternatives.

9.1.3 Surface Water Quality Sampling

Surface water sampling in 2006 demonstrated the relationship between water column concentrations of furan and dioxins, and suspended solids burden. Additional surface water sampling may be undertaken in 2007 once the UTR site characterization is complete. Sampling and analysis strategies for further surface water monitoring will be focused to address specific objectives developed collaboratively with MDEQ.

9.1.4 Geochemistry Fractioning and Stokes Settling Measurements

The initial geochemistry study will be completed by the end of 2006, and the study findings will be included in the February 2007 UTR site characterization report. Understanding the relationship of grain size, mineralogy and other factors that influence the occurrence of furans and dioxins is fundamental to the *GeoMorph*® site characterization. At present it is unclear whether furan and dioxin contamination in sediment and soil can be associated with a particular grain size, the presence of carbon-rich fractions, or some other soil property. However, if such a relationship exists it will be included as a factor in the fluvial geomorphic analysis of contaminant distribution. Further, if there is a relationship between contaminant concentrations and grain size and/or mineralogy, Stokes Law settling studies will be conducted in 2007 to support calibration and verification of the hydrodynamic model, and sediment trap efficiency studies currently underway in the USR.

9.1.5 Flow and Suspended Solids Monitoring

Limited baseline testing of surface water quality in the Tittabawassee River for suspended solids and dioxin and furan content was conducted in 2006 (see Section 3.2.1.3). Additional sampling and testing of river and floodplain water quality will be undertaken during the performance monitoring conducted to demonstrate that any pilot studies and long term corrective action activities undertaken in 2007 are in fact successfully achieving the identified remedial action objectives. In addition, upstream and downstream surface water quality monitoring will be conducted during any intrusive corrective actions in 2007 that occur within the river channel or within 500 feet of the river's edge to document that the corrective action procedures are not contributing to mobilization of COIs into the river.

9.1.6 Bed and Bank Erosion Surveys

No additional bed and bank cross-sectional topographic surveys are planned for 2007. Baseline bed and bank erosion topographic surveys were conducted in 2005 and 2006 and verified the general tendency for accretive conditions in the floodplains and erosive conditions in the river channel, although limitations in the data prevented firm conclusions (see Section 3.1.7.3 in this RIWP). The monuments and survey points used during these surveys will be preserved and may be used in future performance assessments and amendments to the Conceptual Site Model. To improve precision and accuracy, future bed and erosion surveys will also utilize erosion/accretion pins for bank and overbank areas, and similar mechanical devices for in-channel measurements.

9.1.7 Turf Mat Dioxin and Furan Deposition Studies

The turf mat dioxin and furan deposition studies conducted in 2006 yielded informative results relating to the transport and deposition of dioxins and furans in the TR floodplains (see Section 3.2.1.2 in this RIWP). These studies will be repeated in 2007 to extend the gathering of this information and track deposition patterns over time. Additional turf mat locations will be selected in and downstream of the UTR based on the results of the identification of priority areas at high risk of erosion of elevated COI concentrations.

9.1.8 Clay Pad, Dendrogeomorphic, and Geochronology Studies

The clay pad, dendrogeomorphic and geochronology studies conducted in 2005 and 2006 yielded useful information that support the concept that generally accretive conditions exist in the floodplains (albeit with localized erosion scaring). Based on the results of these baseline studies, further clay pad, and dendrogeomorphic and geochronology studies are not presently planned for 2007. Instead, the results of the 2006 *GeoMorph®* characterization work and the multiple lines of evaluation in the UTR discussed above will be used to advance the Conceptual Site Model that will in turn be used in 2007 to develop remedial action objectives as well as to screen corrective action alternatives.

9.1.9 Numerical Hydrodynamic Studies of Tittabawassee and Upper Saginaw Rivers

The numerical hydrodynamic model that was created in 2006 for the Tittabawassee River will be used in 2007 to assess the erosional conditions that exist in the river during a variety of river stage conditions, based on river stage measurements conducted in 2005 and 2006. In addition, the conditions created as a result of the peaking power generation of the Sanford Dam will be modeled along with the conditions that existed in the river and floodway during the 1986 flood. The results of these model runs will be presented in the February 2007 UTR Site Characterization Report. During the remainder of 2007, this model will be used to assess the likely performance and secondary impacts of alternative corrective action scenarios developed in 2007 to address the high levels of COIs being found in the some overbank locations within the UTR.

9.1.10 Numerical Particle Transport Model Simulations

The numerical particle transport model developed in 2006 (see Section 5.2.4.2 of this RIWP) will be used to assess how particles with high COI concentrations came to rest in those areas being found to have high COI concentration during the site characterization and thereby aid in assessing the secondary upstream sources of these particles, and therefore the need for and priorities of corrective actions. In addition, this model will provide an independent tool for assessing the possible downstream impacts of the No Action alternative in those areas where this option is among the alternatives considered viable.

Results will be presented as downstream spatial distributions of settling locations, for particles "released" within a model simulation at a given location at fixed intervals under time-varying flow conditions. Mapping of the spatial distributions of particle settling locations will be performed for release locations of interest for the five 2003-2006 flooding scenarios, including releases from locations that are predicted to be relatively erosional during alternative corrective action scenarios, based on EFDC local velocity and shear stress results.

9.1.11 Initiate Development of Remedial Action Objectives

The results of the UTR site characterization will be used in early 2007 to develop, in consultation with MDEQ, USEPA and the Natural Resources Trustees, the Remedial Action Objectives (RAOs) needed to set corrective action goals for those areas of the UTR with high concentrations of COIs that are subject to risk of erosion and downstream transport and/or which pose unacceptable risks for human exposure. The over-arching goals of the RAOs will be to:

- reduce or eliminate the completed risk pathways that exist for unacceptable human exposures;
- reduce concentrations of COI in the tissue of both resident and migratory fish that are eaten by humans;
- mitigate the past impacts and future occurrences of mobilization and redeposition of COIs from the river channel and overbank to downstream properties and water bodies; and
- minimize disruption to the ecosystem of the Study Area, which has recovered extremely well from the devastation caused by logging operations and massive forest fires at the end of the 19th century.

9.1.12 Geomorphological Mapping of Middle and Lower Tittabawassee River

Mapping of the various geomorphological units in the reaches of the middle and lower sections of the Tittabawassee River will be completed by the end of 2006 for use in developing a SAP for these reaches in 2007.

9.1.13 SAP Development for Tittabawassee River and Priority I and II Properties

In early 2007, a *GeoMorph®* SAP will be prepared for the Middle and Lower Tittabawassee River based on the geomorphic mapping that will be conducted in late 2006. As with the UTR SAP, the lower portions of the Tittabawassee River will be divided into a series of reaches based on the geomorphology and anthropogenic influences along the river. Sampling locations within each reach will be developed in consultation with MDEQ along a sufficient number of transects to define the nature and extent of COI contamination in each of the geomorphological features. As with the UTR SAP, the order of the reach sampling sequence will depend on a variety of factors including the characteristics of the reaches, obtaining access, and the nature of the equipment needed to acquire samples to the necessary depth to define the vertical extent of COI contamination.

During the collaborative development of the SAP, special consideration will be given to sampling reaches containing the Priority I and Priority II residential properties defined in the 2005 Framework Agreement such that these samples will be obtained during 2007. As part of this process, statistical sampling will be conducted to evaluate the representativeness of the *GeoMorph®* site characterization for establishing exposure point concentrations.

9.1.14 Prioritization of UTR Areas With Erosion Risk Using Pilot Corrective Actions Matrix

A Pilot Corrective Actions Matrix (Attachment K) has been developed to assist in organizing and evaluating the multiple environmental aspects of a given area found to contain high levels of COIs and which is at risk of erosion and downstream transport and deposition. In addition, the Pilot Corrective Actions Matrix will include information on the presence of endangered or threatened species and/or sensitive habitat in the vicinity of the area of interest. The Dow consulting team will use this matrix in consultation with MDEQ and USEPA by the end of 2006 to identify areas in the UTR that require pilot projects on selected corrective action strategies to mitigate the risk of erosion and downstream transport of COIs.

9.1.15 Development and Preliminary Screening of Short and Long Term Corrective Action Technologies for Areas With High Risk of Erosion in UTR

Throughout 2006, Dow's consultants have been evaluating alternative corrective action technologies to abate, manage or eliminate the risks posed by COIs in the overbank of the Tittabawassee River. The evaluation process is ongoing as of this writing as information becomes available from the UTR SAP field and laboratory work. The following corrective action alternatives and management strategies are being considered by Dow and its contractors:

1) No Action may be an acceptable alternative where no completed risk pathways are identified.

2) Institutional Controls are likely to be a suitable component of a corrective action strategy where COIs are found below a depth of 12 or more inches of non-impacted soils, the location is not subject to significant erosive forces, and future disturbances of the COIs can be managed through institutional controls, such as deed restrictions and/or management controls.

3) Monitored Natural Recovery (MNR) may be protective where COI concentrations in floodplain soils are close to action limits and where ongoing accretion of clean soils overlying the contaminated soil layers has been adequately demonstrated.

4) Thin Layer Soil Cover is an option where unacceptably high levels of COIs are found close to the ground surface in demonstrably accretive areas where there is not yet sufficient un-impacted soils above to prevent direct contact or wind blown exposure.

5) Capping/Armoring alternatives may be an acceptable corrective action strategy where high levels of COIs are at risk of erosion, the ecological aspects of the area are such that ground surface disturbances will not cause unacceptable adverse ecological impact, and the hydrodynamic impacts of additional cover materials will not exacerbate downstream erosion of sensitive structures or areas of elevated COIs.

6) Removal is an alternative that will address certain high concentration areas at risk of erosion and downstream transport, or there is unacceptable direct contact risk, and where the ecological aspects of the area are such that ground surface disturbances will not cause unacceptable adverse ecological influences. This is the most costly and most ecologically disruptive of the options, with the greatest secondary adverse environmental impacts on the local community. The removal alternative will likely be selected only in those instances where there is no other feasible alternative.

7) Hybrid Combinations of technologies may be favored in certain settings. An example would be the removal of near shore soils followed by capping of the excavation and upland areas.

8) Dam Operation will be evaluated in terms of the risk of water line erosion along cut banks having high levels of COI caused by daily fluctuations in river levels.

9) River Channel Modification is a long term corrective action alternative under consideration by the Dow consulting team. The Tittabawassee River channel has meandered back and forth across the floodway since the last glacial period as is clearly evidenced by the interbedding and layering of surficial soils adjacent to the current river channel. Moreover, the river channel was substantially modified during the logging era by the construction of dams and the alteration of the channel configuration to facilitate booming and rafting of logs downriver. It may be that there are areas of the TR that would be well suited to channel modifications in the form of channel widening to reduce erosive flow velocities, constructed mid-channel vanes to redirect high velocity streamlines away from banks with high COI concentrations, or even “braiding” of the several river channels to create alternative flow paths for river flows during storm events and reduce the erosive velocities in areas of high COI concentration. Conversion of agricultural fields to stream channels could be done with little or no adverse ecological effect and would generate cover soils to be used in other areas requiring capping.

10) Wetland Restoration could be readily accomplished in those areas of the floodplain that have had artificial drainage channels constructed to drain groundwater to the river channel and allow farming activities. By filling these constructed drains across the floodplain, wetland vegetation would emerge, roughness coefficients would increase and the accretive nature of the area could be enhanced with multiple positive impacts to the local ecology.

9.1.16 Corrective Action Performance Evaluation Methodologies

In order to assess the effectiveness of pilot corrective action activities, interim response activities and long term corrective actions performed on the Tittabawassee and Saginaw Rivers, performance evaluations will take place before, during and after corrective action has been implemented.

There are a variety of interim response and long term corrective action alternatives being considered during the ongoing RI work. Some of these alternatives involve changing the hydrology and morphology of the river system to abate erosive velocities in area of high COI concentration. One of the best ways to evaluate these effects will be to have qualified fluvial geomorphologists examine the patterns of erosion evident at the base of these cut banks. In addition, periodic visual examination of those locations where armoring and/or capping are the selected alternative for reducing downstream migration of stored COI will be necessary to assure that the installed barriers to accelerated erosion are withstanding erosive velocities and shear stress and maintaining their physical integrity. The techniques to be used in these performance evaluations will vary depending upon the corrective actions taken and may include:

- Geomorphological analysis supported by the numerical hydrodynamic and particle fate and transport modeling now being developed to test each corrective action concept before it is implemented. This evaluation would assess the likely long term effectiveness of the each corrective action concept at abating downstream transport of COIs stored in the overbanks of the Tittabawassee River, and in the sediments and overbanks of the Upper Saginaw River. The modeling would also assess potential secondary impacts of proposed corrective actions by modeling river velocity and shear stress changes likely to occur as a result of the corrective action.

- During the implementation of intrusive corrective actions within 500 feet of the river channel, surface water column monitoring would be employed to assure that the corrective action activities do not result in mobilization of solids into the water column.

- The continuation of turf mat deposition studies, which have already shown that the COI concentration of sediment being deposited in the floodplains during storm events can be effectively monitored at selected locations. Continued turf mat monitoring is a means of demonstrating over time that corrective actions are effectively and progressively reducing downstream transport of COI now stored in the overbank and sediments of the river systems.

- Resume the surface water monitoring in the river channel and floodway during a storm event to monitor the level of COIs being carried on particulates mobilized by the storm event. The locations used in the 2006 water quality sampling effort would be supplemented with additional monitoring stations immediately downstream of areas that have received corrective action. Time trend evaluation of the data would provide a reliable indicator of the effectiveness of the pilot and long term corrective action technologies employed.

- Continue over time the biological tissue testing for COI concentration described in the Baseline Ecological Risk Assessment (see TR/USR RIWP Volume 2). This testing would periodically examine a wide variety of species important to the bioaccumulation and risk pathways of COI in both terrestrial and aquatic organisms, and will address one of the primary remedial action objectives, which is to reduce tissue concentrations in both resident and migratory fish populations in the Tittabawassee and Saginaw Rivers and in Saginaw Bay. This work may be supplemented by caged fish studies in selected locations. Fish tissue concentrations would be evaluated using time trend analysis to assess the effectiveness of the corrective action program.

9.1.17 Implement *GeoMorph®* Sampling and Analysis for Middle and Lower TR

9.1.18 HHRA Activities in 2007 – (See TR/USR RIWP Volume 2)

9.1.19 ERA Activities in 2007 – (See TR/USR RIWP Volume 2)

9.2 REMEDIAL INVESTIGATION AND FEASIBILITY STUDY WORK PLANNED FOR 2008

The following activities will be conducted in 2008:

- Prepare *GeoMorph®* SAP for USR
- Prioritization of Middle and Lower TR Source Areas at Erosion Risk Using Interim Action Matrix
- Development and Preliminary Screening of Interim and Long Term Corrective Action Alternatives for Source Areas at High Risk of Erosion in Middle and Lower TR
- Implement *GeoMorph®* Sampling and Analysis for USR
- Development and Preliminary Screening of Interim and Long Term Corrective Action Alternatives for Source Areas at High Risk of Erosion in USR
- HHRA Activities in 2008 – (See TR/USR RIWP Volume 2)
- ERA Activities in 2008 – (See TR/USR RIWP Volume 2)

10. SCHEDULE

This section provides an overview of the schedule for the TR/USR RIWP project activities. The following schedule overview was developed based on the current understanding of work processes, regulatory review process, and stakeholder involvement.

- December 1, 2006 – Submit RIWP for the Tittabawassee River and Upper Saginaw River and Floodplains to MDEQ
- February 1, 2007 – Submit UTR *GeoMorph*® Site Characterization Report to MDEQ
- May 1, 2007 – Submit Middle Tittabawassee River *GeoMorph*® SAP to MDEQ
- June 1, 2007 – MDEQ Approval of Middle Tittabawassee River *GeoMorph*® SAP
- Summer 2007 – Implement Upper Tittabawassee River Pilot Corrective Actions
- June 15, 2007 – Commence Middle Tittabawassee River *GeoMorph*® SAP Field Activities
- November 1, 2007 – Complete Middle Tittabawassee River *GeoMorph*® SAP Field Activities
- March 1, 2008 – Submit Middle Tittabawassee River *GeoMorph*® Site Characterization Report
- May 1, 2008 – Submit Lower Tittabawassee River and Upper Saginaw River *GeoMorph*® SAP to MDEQ
- June 1, 2008 – MDEQ Approval of Lower Tittabawassee River and Upper Saginaw River *GeoMorph*® SAP
- Summer 2008 – Implement Middle Tittabawassee River Pilot Corrective Actions
- June 15, 2008 – Commence Lower Tittabawassee River and Upper Saginaw River *GeoMorph*® SAP Field Activities
- November 1, 2008 – Complete Lower Tittabawassee River and Upper Saginaw River *GeoMorph*® SAP Field Activities
- March 1, 2009 – Submit Lower Tittabawassee River and Upper Saginaw River *GeoMorph*® Site Characterization Report to MDEQ
- Summer 2009 – Implement Lower Tittabawassee and Upper Saginaw River Pilot Corrective Actions

The general parameters and assumptions used for developing this schedule are noted below:

- Access agreements are needed before field activities can take place on private properties. No samples will be collected until access agreements are in place to permit the necessary sampling. A time frame of 60 days was assumed for obtaining these access agreements prior to sampling. This includes 30 days to pursue access to locations identified in SAPs. Dow will make its best efforts to obtain access, but cannot control the response time of the third parties involved.

- Field sample collection activities have been scheduled with consideration for seasonal factors and to maximize field activities during the summers of 2007 and 2008.
- Laboratory analysis of environmental samples will take place in an ongoing manner throughout the sample collection event and will be completed on "rapid turnaround" near-real-time basis. Analytical validation of all laboratory results obtained during the implementation of this SAP will also take place on an ongoing basis and will also be completed on a "rapid turnaround" near-real-time basis.
- SAPs will be implemented on a near-real-time basis. Information will be exchanged with MDEQ and USEPA on a mutually agreed upon schedule. Document deliverables will be prepared in time frames that align with their content, complexity, and decision-making needs. Sufficient time is needed to conduct internal reviews/revisions and to verify the quality of all information presented.

Since SAPs will be implemented on a near-real-time basis, it has been assumed MDEQ review and approval periods will be mutually agreed upon but, in general, will facilitate the near-real-time decision making process. Information exchange and MDEQ review and approval periods are considered "critical path" activities, and have the potential to affect the overall schedule because subsequent activities may not be able to start until approval for specific tasks or investigation areas is received.

Dow will make reasonable best efforts to schedule and sequence activities to complete work in a timely manner, including adjusting activities to try and compensate for delays in work due to matters outside Dow's control (for example, access agreements, force majure, weather) if possible.

11. PUBLIC PARTICIPATION PLAN

11.1 SUMMARY

The purpose of this Public Participation Plan is to outline activities that inform residents of the Midland/Saginaw/Bay City areas ("Tri-City" areas) of activities associated with The Dow Chemical Company's (Dow's) offsite corrective actions, conducted pursuant to Condition IX B.3 (c) of Dow's Chemical Hazardous Waste Management Facility Operating License. The Public Participation Plan incorporates the goals and objectives previously established through the Communications Interim Response Activities (IRA), the 'ongoing community involvement process' and aligns with EPA's public participation guidelines.

The Public Participation Plan is intended to inform the Tri-Cities communities about the corrective action process, inform the communities about actions taken or contemplated, and solicit broad community input. With these objectives in mind, the overall goals of the public participation plan are to maintain a neutral and balanced public participation process and make information available to the public on a regular basis.

With approval of the "Framework for an Agreement" (Framework) on January 20, 2005, Lt. Gov. John Cherry supported the development of a public participation process that would be broadly accepted by the community. In March and April 2005, Dow and the Michigan Department of Environmental Quality (MDEQ) jointly convened stakeholders to present the Framework and receive feedback from members of the public on how best to communicate with the public on the dioxin/furan situation going forward. Public feedback culminated in the development of a Community Involvement Process that featured town hall style meetings as a communication tool to provide information to the community, among other communication mechanisms.

The first town hall meeting was held on November 9, 2005. Per the Community Involvement Process and with the assistance of a professional facilitator, the meeting provided face-to-face interaction between residents, Dow and MDEQ. It also served as a forum to provide updates on Interim Response Activities, technical issues, data gathering efforts, and obtain various community perspectives. As a major part of the Public Participation Plan, a series of quarterly town hall meetings were held in 2006 and additional quarterly town hall meetings have been scheduled in 2007.

This document outlines the communication methods, community perspectives, goals and objectives of this ongoing public participation process.

11.2 GOALS OF PUBLIC PARTICIPATION PLAN

Consistent with the ongoing public participation process, the overall goals of this Public Participation Plan are to:

- Solicit feedback from community stakeholders (residents, civic, educational, religious and professional leaders, associations and organizations) on various elements of Dow's off-site corrective actions;
- Inform the Tri-City communities about the corrective action process;
- Inform the Tri-City communities about actions to be taken or completed.

Consistent with the approach of the Communications IRA, Dow will continue to:

- Provide information on the presence of and potential risks associated with exposure to furans/dioxins (and/or other potential constituents of interest) and practical measures that can be taken to mitigate those risks;
- Provide information about the activities associated with Dow's offsite corrective action work performed under the License, including Interim Response Activities.

11.3 CONTENTS OF THE PUBLIC PARTICIPATION PLAN

This Public Participation Plan highlights community perspectives, outlines community involvement activities to be conducted during the ongoing and anticipated future corrective actions and identifies locations where information related to dioxins/furans can be found.

This plan is divided into the following major sections:

- Overview of the Public Participation Plan;
- Public Participation Activities and Schedule.

11.4 PUBLIC PARTICIPATION ACTIVITIES AND SCHEDULE

Public Participation Activities include both written and oral communication to residents of the Tri-City area. Residents have the opportunity to meet with MDEQ and Dow during community meetings and obtain informational materials related to furans/dioxins in local libraries, township halls and internet web sites managed by MDEQ and Dow.

11.5 COMMUNITY MEETINGS

11.5.1 Community Perspectives

In March and April 2005, Dow and MDEQ held four meetings throughout the Tri-City area where the Framework for an Agreement between the State of Michigan and Dow was presented and the public was solicited for input on how Dow and MDEQ should communicate with the community. A summary of insights from the convening meetings is available on MDEQ's website. Several major themes emerged from these meetings:

- Information should be presented clearly and unambiguously;
- The MDEQ and Dow should use a variety of means to convey information to the community;
- People should have meaningful input into the decisions about how historical dioxin releases in the City of Midland, Tittabawassee and Saginaw Rivers, and the Saginaw Bay will be addressed;
- A town hall-style meeting would be an effective forum for communication;
- While there was some agreement that a stakeholder committee could be a valuable tool for providing community input into the decision-making process, the public ultimately decided against forming a stakeholder committee.

Ideas that received broad public acceptance resulted in their implementation:

- Periodic town hall meetings;
- Technical information meetings;
- Professional, neutral facilitator for town hall meetings;
- Meetings conducted with specific agenda;
- Information sheets;

- Dow and MDEQ participation in Community Group Meetings (residents, civic, educational, religious and professional leaders, associations and organizations).

The first of these periodic town hall meetings was held on November 9, 2005. Per the Community Involvement Process and with the assistance of a professional facilitator, the meeting provided face-to-face interaction between residents, Dow and MDEQ. It also served as a forum to provide updates on Interim Response Activities, technical issues, data gathering efforts, and obtain various community perspectives. A transcript of the meeting is available on MDEQ's website.

11.5.2 Upcoming Activities

In 2007, town hall meetings will be held on February 8, 2007, May 17, 2007, August 9, 2007 and November 8, 2007 at the Horizons Conference Center in Saginaw. The Horizons Center was chosen as a central, convenient location for Tri-City residents. Meetings will be held in the late afternoon and early evening for 2-3 hours. Agendas and handouts will be distributed at each meeting. Transcripts of each meeting will be posted to the MDEQ website. The meetings will also be video-taped and aired on local cable television.

In addition to the meetings and transcripts, MDEQ and Dow may independently develop and distribute information sheets providing discussions of topics of interest to the community. Dow may elect to use publicly available mailing lists to inform residents.

11.6 COMMUNITY INFORMATION CENTERS

Community Information Centers (CICs) are located in libraries and township halls throughout the Tri-City area with the primary objectives of:

- Providing written materials to the public about dioxins and furans;
- Located in high-traffic areas of each city or township in or near the Areas of Concern;
- Open and accessible at convenient hours for the public.

Publications are available from the Michigan Department of Community Health (MDCH), Michigan Department of Environmental Quality (MDEQ), Michigan Department of Agriculture (MDA), and Agency for Toxic Substances and Disease Registry (ATSDR) at local libraries and township halls. A plan has been established to monitor the CICs at these locations and replenish documents as needed.

In addition to these publications, other relevant publications may be useful to include in the CIC. Wherever possible, MDEQ and Dow will work together to produce joint publications, however, at times MDEQ and Dow may independently develop and distribute information providing discussions of topics of interest to the community.

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13. GLOSSARY

Accretion	The gradual addition of new land to old by the deposition of sediment carried by the water.
Aquifer	A subsurface strata or zone that is sufficiently permeable to conduct groundwater and to yield economically significant quantities of water to wells and springs.
Aquitard	A confining bed that retards but does not prevent the flow of water to or from an adjacent aquifer; a leaky confining bed. It does not readily yield water to wells or springs, but may serve as a storage unit for groundwater.
Bathymetry	The measurement of the depth of bodies of water.
Bedload	The part of a river's load that is moved on or immediately above the stream bed, such as the larger or heavier particles (boulders, pebbles, gravel) rolled along the bottom; the part of the load that is not continuously in suspension or solution.
Benchmark value	Published generic risk-based values for human and ecological exposure.
Confluence	The point where two or more rivers meet.
Constituents of Interest (COI)	The lists of COI for this project are derived from the PCOI, and reflect those substances that are likely to have been released to the environment during the period of interest for the study. Because of the large number of PCOI, the COI lists have been organized by chemical class to facilitate evaluation of physical/chemical properties and selection of analytical methods. COI may or may not have suitable analytical methods, and therefore may or may not be included on the Target Analyte List.(TAL)
Contaminant of Potential Concern (CoPC)	A Target Analyte List (TAL) chemical present in soil or sediment at a concentration that is greater than background concentrations and relevant risk-based screening values for human health derived either by MDEQ or EPA.
Contaminant of Potential Ecological Concern (COPEC)	Any contaminant that is shown to pose possible ecological risk.
Cut bank	The steep or overhanging slope on the outside of a meander curve. It is produced by lateral erosion of the river.
Flashy	River flow regime characterized by a rapid rate of change.
Floodplain	That portion of a river valley, adjacent to the channel, which is built of sediments deposited during the present regimen of the river and is covered with water when the river overflows its banks at flood stages. The estimated 8-year and 100-year Floodplains represent the extent of the floodplain inundated during floods with recurrence intervals of 8 years and 100 years, respectively.
Fluvial	Of or pertaining to rivers.
Geochronology	Study of time in relationship to the history of the earth.
Geomorphic feature	An identifiable landform such as a levee or a terrace.
Geomorphic polygon	The two-dimensional mapped location of a geomorphic feature.
Geomorphology	The science that treats the general configuration of the earth's surface;

	specifically, the study of the classification, description, nature, origin, and development of landforms and their relationships to underlying structures and the history of geologic changes as recorded by these surface features.
Hazardous substance	Any substance that the Michigan Department of Environmental Quality demonstrates, on a case-by-case basis, poses an unacceptable risk to public health, safety, or welfare, or the environment, considering the state of the material, dose-response, toxicity, or adverse impact on natural resources**.**
Hydrophobic	Lacking strong affinity for water.
Lacustrine	Sediment deposited in a lake environment.
Midland Plant	The Dow Chemical Company Midland Plant in Midland, Michigan
Morphology	The observation of the form of lands.
Natural levee	A ridge or embankment of sand and silt, built by a river on its floodplain along both banks of its channel, especially in times of flood when water overflowing the normal banks is forced to deposit the coarsest part of its load.
Overbank deposit	Silt and clay deposited from suspension on floodplain by floodwaters that cannot be contained within the river channel.
Palustrine	Pertaining to material growing or deposited in a marsh.
Pedogenic	The natural process of soil formation and development, including erosion and leaching.
Photolysis	Chemical decomposition induced by light or other radiant energy.
Photo-oxidation	Oxidation under the influence of radiant energy (as light).
Point bar	One or a series of low, crescent-shaped ridges of sand and gravel developed on the inside of a growing meander of a river or stream by the slow addition of individual accretions accompanying migration of the channel toward the outer bank.
Potential Constituent of Interest (PCOI)	The PCOI for this project consist of those substances on the master list of chemicals submitted by The Dow Chemical Company to MDEQ on June 1, 2006, plus those substances found in biomonitoring of the Tittabawassee and Saginaw Rivers. It is recognized that not all substances on the Dow master list will have significance as environmental contaminants, nor that the substances found in biomonitoring of the two rivers are necessarily related to Dow operations in Midland.
Scoping Study	*Tittabawassee River Floodplain Scoping Study*: CH2M Hill 2005a
Sediment	Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, or ice, and has come to rest on the earth's surface either above or below sea level.
Shear stress	Force produced at the sediment bed as a result of friction between the flowing water and the solid bottom.
Soil	A natural body consisting of layers or horizons of mineral and/or organic constituents of variable thicknesses, which differ from the parent material in their morphological, physical, chemical, and mineralogical properties and their biological characteristics; at least some of these properties are pedogenic.

Splay Deposit typically composed of sandy or silty material found in floodplain areas where floodwaters breach levees or banks formed by reduction in velocity as floodwaters spread out.

Streamline Predicted flow path of a particle under different flow conditions.

Study Area The Study Area for this RIWP is the river channels and 100 year floodplains for the 22 miles of the Tittabawassee River between the Chippewa and Saginaw Rivers, and the upper 6 miles of the Saginaw River from its confluence with the Tittabawassee River down to the 6^{th} Street turning basin.

Suspended load Finer particles that are suspended in the water column.

Target Analyte (TA) An analyte include on the Target Analyte Lists (see below).

Target Analyte Lists (TALs) The Target Analyte Lists are compilations of those substances (elements or chemicals) that will be analyzed in samples from the Study Area. TALs are method specific, and are integral components of the project QAPP and method SOPs. Because of the large number of COI and project samples, not all samples will be analyzed for all TAs.

Thalweg The line drawn to join the lowest points along the entire length of a river bed or valley.

Till Unstratified drift, deposited directly by a glacier without reworking by melt water, and consisting of a mixture of clay, silt, sand, gravel, and boulders ranging widely in size and shape.

Unconsolidated A sediment that is loosely arranged or unstratified, or whose particles are not cemented together, occurring either at the surface or at depth.

14. ACRONYMS AND ABBREVIATIONS

°F	Degrees Fahrenheit
1984 Report	*Point Sources and Environmental Levels of 2,3,7,8-TCDD (2,3,7,8 – Tetrachlorodibenzo-p-Dioxin) on the Midland Plant Site of The Dow Chemical Company of Midland, Michigan* (November 5, 1984)
ANOVA	Analysis of Variance
ATS	Ann Arbor Technical Services, Inc.
ATSDR	Agency for Toxic Substances and Disease Registry
BERA	Baseline Ecological Risk Assessment
bgs	Below ground surface
bss	Below sediment surface
cfm	Cubic feet per minute
cfs	Cubic feet per second
CIC	Community Information Centers
Cm/sec	Centimeters per second
COI	Constituent of Interest: The lists of COI for this project are derived from the PCOI, and reflect those substances that are likely to have been released to the environment during the period of interest for the study. Because of the large number of PCOI, the COI lists have been organized by chemical class to facilitate evaluation of physical/chemical properties and selection of analytical methods. COI may or may not have suitable analytical methods, and therefore may or may not be included on the Target Analyte List.(TAL)
CoPC	Contaminant of Potential Concern**:** A Target Analyte List (TAL) chemical present in soil or sediment at a concentration that is greater than background concentrations and relevant risk-based screening values for human health derived either by MDEQ or EPA.
COPEC	Contaminant of Potential Ecological Concern: Any contaminant that is shown to pose possible ecological risk.
CSM	Conceptual Site Model
CWS	Clear Water Sewer
DDD	Dichloro-diphenyl-dichloroethane
DDT	4,4’-(2,2,2-Trichloroethane-1,1-diyl)bis(chlorobenzene)
DGPS	Digital Global Positioning System
dioxin	Polychlorinated dibenzo-p-dioxin
Dow	The Dow Chemical Company
DQO	Data Quality Objective
EF	Erosion Factor
EFDC	Environmental Fluid Dynamics Code
ERA	Ecological Risk Assessment

FEMA	Federal Emergency Management Agency
furan	Polychlorinated dibenzo-p-furan
Fv	Vapor Pressure
GPS	Global positioning system
HASP	Health and Safety Plan
HHRA	Human health risk assessment
IWS	Ionizing Wet Scrubber
License	Hazardous waste management facility operating license
LiDAR	Light Detection and Ranging
MACT	Maximum Achievable Control Technology
MCV	Midland Cogeneration Venture
MDCH	Michigan Department of Community Health
MDEQ	Michigan Department of Environmental Quality
MDNR	Michigan Department of Natural Resources
mg/L	Milligrams per liter
MNFI	Michigan natural features inventory
msl	Mean sea level
MSU	Michigan State University
NPDES	Nation Pollutant Discharge Elimination System
NRT	Near-Real-Time
PAH	Polynuclear Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyls
PCOI	Potential Constituent of Interest: The PCOI for this project consist of those substances on the master list of chemicals submitted by The Dow Chemical Company to MDEQ on June 1, 2006, plus those substances found in biomonitoring of the Tittabawassee and Saginaw Rivers. It is recognized that not all substances on the Dow master list will have significance as environmental contaminants, nor that the substances found in biomonitoring of the two rivers are necessarily related to Dow operations in Midland.
PCSM	Preliminary Conceptual Site Model
ppt	Parts per trillion or picograms per gram
PRM	Probalistic Risk Assessment
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
R 299.5528	Michigan Administrative Code, Rule 299.5528
RCRA	Resource Conservation and Recovery Act
RGIS	Revetment Groundwater Interception System
RI	Remedial Investigation
RIWP	Remedial Investigation Work Plan
S3TM	*Sampling Strategies and Statistics Training Materials for Part 201 Cleanup Criteria*: MDEQ 2003b
SAP	Sampling and Analysis Plan

SLERA	Screening-Level Ecological Risk Assessment
SLRA	Screening-Level Risk Assessment
SOW	Scope of Work
SR	Saginaw River
SSCC	Site-Specific Cleanup Criteria
SVOC	Semivolatile Organic Compound
SWAC	Surface Weighted Average Concentration
TA	Target Analyte
TAL	Target Analyte List: The Target Analyte Lists are compilations of those substances (elements or chemicals) that will be analyzed in samples from the Study Area. TALs are method specific, and are integral components of the project QAPP and method SOPs. Because of the large number of COI and project samples, not all samples will be analyzed for all TAs.
TCDD	2,3,7,8-Tetrachloro-dibenzo-p-dioxin
TEF	Toxic Equivalency Factor
TEQ	Toxic Equivalent Quotient
TOC	Total Organic Carbon
TR	Tittabawassee River
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
USR	Upper Saginaw River
UTR	Upper Tittabawassee River
VOC	Volatile organic compound
WHO	World Health Organization
WSS	Water Settling Sewer (?)
WWTP	Wastewater Treatment Plant